AN IN VITRO ANALYSES OF THREE BODY WEAR SIMULATION IN FOUR POSTERIOR RESIN COMPOSITES

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CERTIFICATE

This is to certify that this dissertation titled **"AN IN VITRO ANALYSES OF THREE BODY WEAR SIMULATION IN FOUR POSTERIOR RESIN COMPOSITES"** is a bonafide record of work done by **DR.BHARATH.N** under our guidance during his postgraduate study period between 2009-2012.

This dissertation is submitted to **THE TAMILNADU Dr.M.G.R.MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY – CONSERVATIVE DENTISTRY AND ENDODONTICS, BRANCH IV**. It has not been submitted (partial or full) for the award of any other degree or diploma.

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INTRODUCTION

The ultimate goal of dental restoration is to replace the biological, functional, and esthetic properties of healthy tooth structure [21]. As an alternative to amalgam, the early attempts to place composites in posterior teeth had only limited success, because of insufficient material properties[35].

Dental composites are polymeric materials based on methacrylate resin monomers that create a three dimensional polymer network when polymerized. Dispersed phase of these materials is composed of reinforcing inorganic filler particles of variable shape and size and bonded to the polymer network by a bifunctional silane coupling agent.[48] The most important factor that limits the usage of composites in posterior area is that they do not have enough resistance to wear and mastication strength.[35]

Wear can be defined as the ultimate consequence of interaction between surfaces which is manifested in gradual removal of material.[34] Wear is a natural process that occurs whenever two or more surfaces contact one another.[62] Wear of dental composites include diverse phenomena as adhesion, abrasion, attrition, chemical degradation and fatigue.[34]

Wear can be related to either material or clinical factors. Material factors relate to the resin composites filler particle size, content, shape, hardness, inter particle spacing, silane coupling agent ,and the nature of matrix, all of which play an important role in composite materials wear resistance.[28] The clinical factors includes various manipulative technique such as etching ,bonding, degree of cure, intensity ,type, and duration of light used for curing and placement of the material.[13]

The wear process of dental composites is complicated by the fact that filler and matrix consist of fundamentally different materials, the relative influence of which varies with wear type.[28] Wear resistance of restorative materials is important for clinical longevity, aesthetics, and resistance to dental plaque. With patients keeping their natural dentition longer, the potential for tooth and restoration wear is greater and is increasingly becoming a clinical problem. [62]

To improve wear resistance of posterior resin composites, various modifications have been made in the filler technology and resin chemistry, for minimizing filler exfoliation during wear.[19] Developments in the filler technology have led to significant reduction in filler size, and improvements in filler packing, reducing the wear and degradation associated with polymer matrix.[31]

Microhybrid composites contains 60% to 70% filler by volume, depending on the density of the filler, translates into 77% to 84% by weight and the main advantage is that it combines the strength of traditional composites and esthetics of micro fine fillers.[9]

Nanocomposites are relatively new generation of composites that has a combination of nanofillers and nanoclusters.[38] Nanocomposites combines the advantage of hybrid and microfilled composites, exhibit higher surface quality as well as increased wear resistance.[12]

Matrix composition is a significant factor in abrasive wear.[28] Several innovative changes have been made in the resin matrix chemistry, since the advent of traditional resin composites. Recently ormocer and silorane technology have been introduced to modify resin matrix.[57]

In 1998, first restorative material based on ormocer technology has been synthesized, which is an inorganic- organic co polymer. Inorganic-organic network matrix is formed through poly condensation, and the filler particles are embedded in to this cross linked inorganic – organic matrix.[64] Matrix in ormocer is characterized by an inter penetrating network of inorganic-organic copolymers, which exhibits significantly less wear than other composite.[35]Ormocers consist of a

long back bone of silicon instead of carbon, on which carbon- carbon double bond containing side chains are grafted to allow the polymerization using conventional photo intiators.

Recently in 2005 experimental silorane based composites have been developed by Wienmenn, et al [57] which are low shrinkage materials, which is a combination of siloxane and oxirane functional moieties, that polymerizes by cationic ring opening mechanism.[24]

Siloxane determines the highly hydrophobic nature of siloranes while oxirane is responsible for lower shrinkage .This new monomer is capable of being polymerized in dark which is called self or dark polymerization.[22] The dark reaction usually is time dependent and may attribute to the strength and hardness of the material [22].Additionally the cyclo siloxane back bone contributes to the higher hardness and wear resistance.[56]

Abrasive wear is believed to be the main wear mechanism in Contact free area, where the material loss is caused by frictional surface interactions with food bolus, and fluid components during chewing.[28] Abrasive wear of resin composites by three body action gradually removes the soft resin matrix between the hard filler particles,

eventually the particles are left unsupported and are easily exfoliated leaving a layer of unprotected resin which wears away rapidly.[62]

The aim of the present in vitro study was to evaluate and compare the wear resistance of four posterior resin composite materials using three body wear simulation method.

The objective of the present in vitro study was to evaluate and compare the wear resistance of four posterior resin composite materials namely a nano hybrid composite (*z350*). Silorane based composite (*p90*). Ormocer based composite –*Admira*, and Packable composite – *surefill*.

1. By measuring the weight loss using a highly sensitive physical balance at various number of cycles from 5000-30,000 cycles.
2. By measuring the wear depth using a surface profilometer at various number of cycles from 5000-30,000 cycles.
3. To characterize wear surface by scanning electron microscope and optical microscope, at the end of 30,000 cycles.

REVIEW OF LITERATURE

Powers et al [45] in 1975 developed a two-body, wear-testing method and the test results were used for comparing and ranking the rate of wear for an amalgam, an experimental composite resin, and a commercial composite resin. The ranking of wear found by this method was the same as that shown by clinical research for the rate of wear of amalgam and commercial composite resin.

Powers et al [46] in 1979 evaluated the wear of micro filled composites, a visible light cured composite, and a conventional composite by two-body abrasion and single-pass sliding. They concluded that tangential forces, wear track widths, surface failure modes and abrasion rates were found to vary among materials.

Derand et al [9] in 1980 performed a study on the abrasion of dental composites stored in different solutions for six months and concluded that there was no difference in wear resistance between the water and lactic acid group, the composite with regular filler showed reduced wear resistance when compared with a micro filler composite.

McKinney et al [37] in1982 evaluated the relationship between subsurface damage and wear of dental restorative composite using pin

on disc wear measurements over a stress range from 2.5-20mpa the wear rates were found to increase suddenly during wear at times tended to decrease with increasing stress and concluded that wear results from the build up of sub surface damage.

Powers et al [47] in 1983 evaluated the wear characteristics of aged and un aged composite restorative materials using single pass sliding. They found that there were differences in wear track widths tangential forces, and surface failure between aged and un aged composites. And concluded that changes in surface wear characteristics upon aging were attributed to surface degradation in the composite materials.

Lutz et al [33] **i**n1984 analyzed the influence of cavity size, material composition, and curing mechanism on wear resistance of MOD resin restorations and they concluded that wear resistance tends to increase both as cavity size decreases, and also from chemical to light- to heat-cured. As to wear, among the composite resins tested, there was no acceptable resin-based amalgam substitute.

Sarrett et al [51] in 1991 evaluated the three-body wear resistance of a hybrid, a small-particle, and a microfilled composite after water storage. They found that, the hybrid composite showed no loss of wear

resistance as a result of water storage. The small particle composite showed a decrease in wear resistance after water storage and concluded that the filler dislodging is a complex process that cannot be simulated with the in vitro wear method.

Kawai et al [27] in 1995 evaluated the OCA wear by means of a three-bodied wear device .After repeated cycles of loading, the OCA wear loss was measured with a profilometer, and the worn surfaces were observed through scanning electron micrography, and they concluded that the difference in wear characteristics is derived from the mechanism by which the filler particle is bonded to the resin matrix.

Mair et al [34] in 1996 reviewed the fundamental mechanisms, manifestations and measurement of wear in dentistry. They found that wear is a net result of a number of fundamental processes such as abrasion, adhesion, fatigue and corrosive effects, which act in different combinations on the various classes of materials. Although wear can be categorized at the chair side, its precise measurement involves the use of replica models and surface contouring. And they concluded that the management of clinical wear requires a proper understanding of the underlying mechanisms.

Soderholm et al [12] in 1996 determine matrix selection, filler composition, and filler silanization affect filler leachability of composites after storage in the simulated saliva and water .They found a large difference between filler leaching in artificial saliva and in distilled water, as well as the interaction between storage medium and filler, cast doubt on the clinical relevance of in vitro studies using distilled water.

Venhoven et al [57] in 1996 determined the filler parameters on the mechanical coherence of dental restorative resins composites they revealed filler particle size is important for the mechanical coherence of dental resin composites which are used for posterior restorations. In the range of the current composites a smaller particle size is desirable. The better mechanical coherence for composites with smaller particles found in an in vitro erosive wear test is probably related to the size of food fibres, which are part of the erosive medium. And they concluded that that there is a critical value of the filler particle size, under which the food fibres are not able to penetrate in the inter particle space, so the erosive capability of the erosive medium will be reduced.

Condon et al [7] in 1997 used an oral-wear simulating machine to explore the effects of factors on abrasion and attrition wear as well as on opposing enamel wear. Samples were cycled 50,000 times against an

enamel antagonist in the oral wear simulator to produce abrasion and attrition simultaneously. Wear depth was measured by profilometry. They concluded that wear increased linearly as the percent of silane treated fillers was reduced. Compositional factors including degree of cure, filler level and silanation directly affected the wear resistance of dental composites

Ferracane et al [12],in 1997 studied the degree of conversion (DC) in composites to test the hypothesis that resistance to wear and marginal breakdown could be improved by enhanced curing they concluded that the resistance to abrasive wear of a dental composite could be improved by enhancement of its degree of conversion.

Yap et al [60] in 1997 compared the effects of immediate and delayed finishing/polishing procedures on the surface characteristics of tooth coloured restoratives including a microfilled, a heavily filled and a polyacid modified composite resin and a resin modified glass ionomer cement. They found that effects of delayed finishing/polishing procedures on surface roughness and hardness appear to be both material and technique dependent. They concluded that for all materials, delayed finishing/polishing with the various techniques generally

resulted in a surface of similar hardness to or harder than that obtained with immediate finishing/polishing and the control group.

Baran et al [2] in1998 ascertained the influence of glass transition temperature, liquid sorption, and small amounts of filler on indentation response. They revealed that no cracking occurred in any material after indentation by pyramid or spherical indenters with diameters equal to or smaller than 0.254 mm. and concluded that indentation with suitably large spherical indenters provoked an elasto plastic response in polymers, and crack morphology was correlated with yield strain.

Hu et al [20] in 1999 compared the relative wear resistance of a selection of current dental composites and amalgams under cyclic loading to explore the wear mechanisms operating on these materials and to assess their relative potential clinical wear resistance under variable masticatory loads and concluded that the wear of Ultrafine Compact-Filled composite and micro filled composite differed and reflect different operative wear mechanisms. For amalgams, the size, shape, and composition of the particles had an effect on the wear resistance of the materials

Htang et al [19] in 1999 evaluated the effects of filler level on the fatigue impact resistance of resin composite. they revealed an inverse

linear relationship tended to exist between filler level and fatigue resistance of the composite materials beyond a certain level of filler content. And concluded that increased filler level does not necessarily improve the fatigue resistance of a resin composite as determined by applying a repititive impact load.

Manhart et al [35]in 2000 determined the flexural strength, flexural modulus, fracture toughness and wear resistance of three packable composites and a packable ormocer in comparison with an advanced hybrid composite and an ion releasing composite Wear of the materials were determined in a pin-on-block-design with a spherical antagonist at 50 N vertical load and quantified by a replica technique using a 3D-laser scanner and they concluded that the tested packable composite resins differed significantly in their mechanical properties. The fracture and wear behavior of the composite resins are highly influenced by the filler system.

Yap et al [61] in 2001 used a reciprocal compression sliding wear device to investigate the influence of contact stress on OCA wear of four resin composite restoratives. The pattern and mechanisms of wear, and the relationship between wear and composite surface hardness were also studied. they concluded that the influence of stress on wear and counter-

body loss was material dependent. The wear mechanisms for the different composites varied depending on their microstructure and the contact stress. There was no significant correlation between material hardness and counter-body loss.

Yap et al [62] in 2001 studied the three-body abrasive wear resistance and wear patterns of five composite restoratives. The possible relation between three-body wear and surface hardness was also investigated. Three-body wear instrumentation was used to investigate the wear resistance of five composite restoratives and concluded that for the composite restoratives, correlation between hardness and wear was significant, and concluded that there is a significant negative but weak correlation exists between hardness and three-body wear of composite restoratives.

Ruddella et al [49] in 2002 investigated the method of producing pre-polymerized fused-fiber filler modified composite particles and the effectiveness of incorporating these novel filler particles into dental composites and concluded that PP-FFMC particles have the potential to improve the wear properties of dental composites, however, they adversely affect the fracture behavior,

Existing processing techniques for these particles, which introduce imperfections, limit their current usefulness.

Lim et al [31] in 2002 determined the effect of filler content and surface treatment on the wear of microfilled composites. Abrasion and attrition wear were evaluated in vitro in a wear tester with an abrasive slurry and a human enamel antagonist. The surface of the wear patterns and the distribution of filler particles were examined using a scanning electron microscope and digital imaging. They found that as the filler volume increased, wear was reduced regardless of filler treatment. They concluded that wear resistance of microfilled composites is enhanced by higher filler volumes irrespective of surface treatment, but good filler/matrix adhesion is needed to minimize wear

Yap et al [63] in 2002 evaluated the effects of cyclic loading on OCA wear and the presence of fatigue wear mechanisms in four composite resin using a reciprocal compression sliding test apparatus. Wear depth was measured using profilometry and the worn specimens were subjected to S.E.M. and they concluded that effects of cyclic loading on wear is material dependent some material exhibit fatigue wear other exhibit deep microcrack formation with extended cyclic

loading the latter may precipitate catastrophic failure despite the low wear observed.

Gohring et al [13] in 2002 performed a laboratory study to test attritional and abrasive wear behavior of composite materials compared to wear behavior of human enamel. All specimens were subjected to long-term thermo-mechanical loading in a computer-controlled masticator, chemical degradation and toothpaste abrasion .and they concluded that beside of attritional wear in OCA, attention must be given to stable filler–matrix interfaces and prevention of water sorption.

Clelland et al [6] **in** 2003evaluated and compared the wear characteristics of two conventional and two packable composites. Opposing enamel wear was also measured. One traditional hybrid composite, one micro-filled composite and two packable composites were formed into disks and used as substrates for the wear test. They evaluated abrasive wear and attrition of the composite materials and wear of the opposing enamel and concluded that packable composites may have improved wear resistance over some conventional composites. Clinical studies are needed to evaluate packable composites over time.

Halvorson et al [16] in 2003 examined the influence of filler loading and silane content on the conversion of photo

activated, resin-based composites. and they concluded that a corrected resin matrix conversion can be estimated by adjusting for silane unsaturation. Additionally, increasing filler-to-resin ratio progressively decreases conversion independent of the presence of silane on the filler.

Hu et al [21] in 2003 explored the fundamental wear behavior of a dental composite with different filler loadings under two-body wear conditions. A two-body wear test was conducted on the experimental composites using a wear-testing machine. The machine was designed to simulate the impact of the direct cyclic masticatory loading that occurs in the occlusal contact area in vivo and concluded that, under two-body wear conditions, addition of high levels of filler particles into the resin matrix could reduce the wear resistance of dental composites.

Mitra [38] **et al in 2003** measured the nanocomposite's properties in comparison with hybrids, micro hybrids and microfills .They studied the compressive, diametral tensile and flexural strengths, in vitro three-body wear, fracture resistance; polish retention; and surface morphology after toothbrush abrasion. and concluded that the dental nanocomposite system showed high translucency, high polish and polish retention

similar to those of microfills while maintaining physical properties and wear resistance equivalent to those of several hybrid composites.

Turssi et al [54] in 2003 reviewed the phenomenon of wear and the major underlying process involved such as adhesion, abrasion, fatigue, and corrosion. And also focused on factors that contribute both to the magnitude and minimization of resin composite wear. Finally, insights were included on both *in vivo* and laboratory studies used to determine wear resistance.

Nagarajan et al [41] in 2004 determined the in vitro two body contact wear mechanisms of three medium filled composites and compared with a highly filled composite previously investigated. The wear tracks were analyzed by scanning electron microscope and Fournier transform infrared spectroscopy to elucidate the wear mechanisms .It was concluded that variations in filler particle size and slight differences in chemical composition of the glass fillers do not affect the in vitro wear rates of these composites.

Zantner catharina et al [65] in 2OO4 determined the influence of particle size, particle material and morphology on the sliding wear of 19 light curing, commercially available composites. Eight specimens of each material were tested in a pin on block design with a oscillating

sliding of degussit antagonist 5 mm diameter at a vertical load of 50 n the horizontal excursion of the antagonist was 8mm. and concluded the wear of the hybrid composite and the microhybrid composite was higher than that of the micro filled composites

Tagetrian et al [53] in 2004 evaluated the surface roughness, hardness and wear resistance of ormocer polymerized by plasma arc system and investigated the two placement technique bulk or incremental layers and they concluded that ormocer demonstrated highest micro hardness and wear resistance values when compared with a hybrid composite. Also light activated composite resin exhibited higher surface hardness values when polymerized with conventional rather than with plasma arc systems.

Yap et al [64] in 2004 investigated the wear resistance of recently introduced nanofill, ormocer composites and compared their wear characteristics to microfill, minifill and polyacid modified composites.. The specimens were conditioned for one week in distilled water at 37°C and subjected to wear testing at 20 MPa contact stress against SS counter-bodies using reciprocal compression sliding wear instrumentation. Distilled water was used as lubricant. Wear depth was measured using profilometry every 5,000 cycles up to 20,000 cycles.

Wear of the materials was cycle and fatigue dependent and concluded that the wear resistance of nanofill and ormocer composites was comparable or superior to polyacid-modified, microfill and minifill composites.

Turssi et al [56] in 2005 evaluated the filler features and their effects on wear and degree of conversion of particulate dental resin composites, wear testings' were conducted and quantified after 100000 cycles using profilometer. Degree of conversion was measured by FTIR spectroscopy and concluded that at specific sizes and combinations, the presence of small filler particles, either spherical or irregular, aid in enhancing the wear resistance of composites without compromising the percentage of reacted carbon double bonds.

Turssi et al [55] in 2005 assessed the behavior of nano structured composites resulting from either abrasion and fatigue loading. A surface profile was recorded using a three-dimensional profiling system, and the specimens were subjected to three-body abrasion. The volume loss and maximum depth of the wear facet on each specimen were calculated. And they concluded that wear and fatigue resistance, of nano-structured composites may perform

either similarly or comparatively worse than a microfilled composite.

Weinmann et al [58] in 2005 compared the profile of a silorane based composite which polymerizes by a cationic ring opening process with the product profile of different methacrylate based restoratives and showed that the silorane composite revealed lowest polymerization shrinkage among tested composites. and concluded that the ring opening chemistry of the siloranes enables at the first time shrinkage values lower than 1 vol% and mechanical parameters such as Modulus of elasticity and flexural strength were comparable to those of clinically well accepted methacrylate based composites.

Lambrechts et al [28] in 2006 reviewed the degradation processes that are encountered on the materials used in dentistry. Various wear mechanisms such as abrasion, attrition &various types of wear. Influencing factors, measuring methods, results of various wear rates and newer technologies were discussed and concluded that posterior resin composites should have a good packability, clinical handling and possibilities of repair

Lambrechts et al [29] **in 2006** analysed the various types of wear, with a description of the different wear simulating devices will allow us

to better understand the multi factorial nature of wear. And they concluded that Wear is a complex process that can hardly be simulated while controlling all variables. extra polation of the in-vitro wear results to the in-vivo situation is difficult because there is a lot of interplay with biological factors that are difficult to simulate.

Heintze et al [17] in 2006 evaluated two ceramic materials as possible substitutes for enamel using two wear simulation methods, and to compare both methods with regard to the wear results for different materials. Flat specimens of one compomer and three composite materials were fabricated and subjected to wear using two different wear testing methods and two pressable ceramic materials as stylus and concluded that the wear generated by the enamel stylus was not statistically different from that generated by the other two ceramic materials.

Ilie et al [22] in 2006 examined the characteristics of an innovative composite material for dental restorations based on silorane monomer with a new chemical composition, and compared with methacrylate based composites they found that modulus of elasticity of the silorane based material was slightly lower and the creep resistance was found to be higher than a methacrylate composite and concluded that siloranes

exhibited good mechanical properties comparable to those of clinically successful methacrylate-based composite materials. .

Luetal [32] in 2006 compared the mechanical properties, generalized wear resistance and polymerization shrinkage of a resin composite filled with spherical inorganic filler to other commercial resin composites. The specimens were tested on an Instron testing machine and concluded that, the microfilled composites had lower strength than the other composites except enamel for CS. All the materials had a similar shrinkage pattern in that about 99% of shrinkage occurred in less than 24hours.

Bottenberg et al [4]**,** in 2007 evaluated the performance of two small particle hybrid ormocer based restorative systems and newer small particle hybrid bisGMA based composite restorative system in occlusal stress bearing restorations. The clinical performance was scored according to USPHS criteria and evaluation of bite wing radiographs and concluded that there was no significant difference in failure ormocer based and bis GMA based restorative systems.

Ataia et al [1] in 2007 evaluate abrasive wear of a dental composite based on a leucite containing ceramic filler, and to compare it with the wear of a composite based on commonly used aluminum barium silicate

glass filler showed that there were significant differences among the abrasive wear of the composites, and concluded that, Using leucite containing glass as an alternative for aluminum barium silicate glass fillers in dental composites generated a significant increase in the wear resistance of the resin composites which should be beneficial in the development of dental materials.

Heintze et al [18] in 2007 compared different wear quantification methods with a series of materials that exhibit different wear rates in the Willytec wear simulator. The volume and maximal vertical loss were quantified directly on the specimens with a profilometry device and concluded that all three sensors are suitable for the quantification of wear facets due to speed and simplicity, the laser sensor has greater advantages over the two other sensors.

Eicka et al [11] in 2007evaluated the properties of silorane based resins and Composites containing a stress reducing monomer. Resin mixtures and composites were formulated containing a developmental stress reducing monomer TOSU and showed that polymerization stress values for resins containing TOSU were less than the other materials and concluded that the ability TOSU to reduce the polymerization stress without a

proportional reduction in mechanical properties provides a basis for improvement of silorane based composites.

Buergers et al [5] in 2007 compare the susceptibility of one novel silorane based and four conventional methacrylate-based resin composites to adhere oral streptococci. Surface roughness was assessed by perthometer measurements, and they found that low bacterial adhesion, were found for silorane based composite When compared against four conventional methacrylate composite resins, streptococcal adhesion seems to be reduced on a silorane based composite resin. This might result from its increased hydrophobicity.

Jung et al [25] in 2007 evaluated the surface geometry of four nanocomposites and one hybrid composite after finishing with rigid rotary instrument. Evaluation of the surfaces was done with laser stylus profilometry and they concluded that that the use of a 30 μm diamond caused detrimental surface alteration on all types of composites. A remarkable number of porosities were detected on the nanofilled composites.

Lee et al [30] in 2007 measured the discoloration as well as the change in staining of composite resins after wear simulation. Generalized wear simulation was performed with a three-body wear

testing device. They found that staining in non worn surface was higher than that in worn surface and they concluded that generalized wear simulation resulted in acceptable color change before staining after staining, color difference between non worn and worn surface increased to not-acceptable value in one composite resin investigated.

Mayworm [36] et al in 2008 compared the wear resistance and hardness of two dental nano hybrid composites and to evaluate the influence of artificial saliva storage on those properties. Artificial saliva storage increases the materials' wear resistance, suggesting that in both materials bulk post-cure takes place and saliva absorption occurs only on the surface of the composites. and concluded that surface micro hardness of the composites decreases after storage in artificial saliva whereas bulk micro hardness of the materials increases.

Moraes et al [39]in 2008 evaluated weight loss and surface roughening after tooth brushing of different resin composites: one packable, one micro hybrid, one nano hybrid and one microfilled composites were used and they concluded that the composites with larger fillers presented higher weight loss and roughening than the finer materials. For both evaluations, control specimens showed no significant

alteration. No significant relationship between loss of weight and roughness alteration was detected.

Niheia et al [42] in 2008 evaluated the wear resistance of resin composite materials with fillers which were modified with a novel hydrophobic silane coupling agent. The novel silane coupling agent containing hydrophobic p-MBS was synthesized. Three body wear test was done with the ACTA machine and concluded that the resin composites containing fillers modified with the novel hydrophobic silane has high wear resistance because of the coupling layers treated with this silane had an excellent affinity with the base resin and formed a highly hydrophobic layer on the filler surface.

Rodrigues Junior [48] characterized the microstructure and composition of two different composites, and to determine their influence on the physical properties and fracture behavior. The micro structural organization of the composites determines their physical properties, in spite of the similar filler content. And concluded that the microstructure did not influence the fracture behavior and the structural reliability of these highly filled composites.

Bhamra et al [3]in 2009 examined the impact of halogen irradiance on the short and long term wear behavior of four methacrylate resin based composites and showed that the increased number of ploughing actions of the antagonist on the RBC results in increased friction which play a major role in the wear process. They concluded that there was a significant increase in the mean total volumetric wear, but not the mean maximum wear depth, observed over time.

Praveen Samuel et al [50] in 2009 determined influence of nano sized filler particles and agglomerates of nano particles in resin based composite materials on the bi-axial flexural strength following cyclic pre loading and storage in dry and/or wet environment. And they concluded that nano clusters provided a distinct reinforcing mechanism compared with the micro hybrid, nano hybrid, micro fill resin based system resulting in significant improvement of strength ,irrespective of environmental storage and testing conditions Silane infiltration within interstices of the nano clusters modify the response to pre loading stress, and enhances the damage tolerance and improved clinical performance.

Ilie et al [23] in 2009 analyzed the mechanical behavior of the silorane based composite with six homologous meth acrylate based composites. The strongest influence on the mechanical properties at macroscopic level was exerted by the storage media at micro and nanoscale. And they concluded that mechanical properties measured at macro, micro, and nanoscale showed that the silorane based composite was comparable to clinically successful methacrylate based composite materials

Palaniappanetal [43] 2009 Compared the 3-year clinical Performance of a nano composite and a microhybrid composite, Filtek Supreme and Z100 restorations . Restorations were Evaluated at baseline and 6, 12, 24, 36-months of clinical Service according to modified USPHS criteria and concluded that within the limitations of the current trial, it can be concluded that Filtek Supreme and Z100 meet the ADA Acceptance Guidelines for tooth-colored restorative materials for posterior teeth.

Curtis et al [8] in 2009 determined influence of nano sized filler Particles and agglomerates of nano particles in resin based Composite materials on the bi-axial flexural strength following cyclic pre loading and storage in dry and/or wet environment. And they concluded that

nano clusters provided a distinct reinforcing mechanism compared with the micro hybrid, nano hybrid, micro fill resin based system resulting in significant improvement of strength ,irrespective of environmental storage and testing conditions silane infiltration within interstices of the nano clusters modify the response to pre loading stress, and enhances the damage tolerance and improved clinical performance.

Ferracane et al [11] in 2010 reviewed a broad range of mechanical properties, handling characteristics, and esthetic possibilities dental composite materials. with the major emphasis to produce materials with adequate strength and high wear resistance and polish retention, and addressed the issue of polymerization shrinkage and its accompanying stress, which may have deleterious effect on the composite and concluded that there is no one ideal material available to the clinician, but the commercial materials that comprise the current armamentarium are of high quality and when used appropriately, have proven to deliver excellent clinical outcomes of adequate longevity.

Guiraldo et al [14] in 2010 investigated the influence of different composite resins Filtek P90 and Heliomolar on light transmission and decrease in Knoop hardness between the bottom and top of cured specimens and concluded that the DKH of Filtek P90 was significantly

higher than that of Heliomolar and concluded there was a greater degree of subsurface polymerization of the methacrylate-based composite compared to the silorane based composite.

Janus et al[24] in 2010 assessed the surface roughness and morphology of three nano composites polished with two different polishing systems the average surface roughness before and after polishing was measured using optical profilometry and showed that there is a positive correlation between the average filler size and the surface roughness suggest that using nano particles in the formulation does not necessary improve the surface texture and concluded that the nano filled composite FS, which contains only nano fillers, showed the best results when associated to SofLex polishing discs.

Wen lien et al [59] in 2010 analyzed the physical properties of a new silorane based restorative material in comparison to five methacrylate based restorative materials a compomer, giomer, nano composite, hybrid and micro-hybrid and concluded that the silorane based material had relatively higher flexural strength/modulus, fracture toughness, but relatively lower compressive strength and micro hardness than the methacrylate -based restorative materials.

Patnaik et al [44] in 2010 studied the abrasive wear behavior of randomly oriented glass fiber (RGF) reinforced with epoxy resin filled with Al2O3, SiC and pine bark dust. The mechanical and three-body abrasives wear behavior of the composites has been studied. And they observed the predominant wear mechanisms in the case of Al2O3 composite were plastic deformation, micro-cutting, pitting in the matrix, and fibre removal and concluded that predominant composite wear mechanisms were micro-cutting, ploughing, fragmentation of wear debris in the matrix and excessive deterioration of fibre surface followed by delamination.

Karabela et al [26] in 2011 Analyzed the physical mechanical properties of nano silica particles .Silica nano particles with average particle size of 40,20,16,14 and 7 nm used as filler were silanized with the silane 3 MPS and the amount of silane was kept constant at 10% relative to the filler weight to ensure the complete silanization of the nano particles and they concluded that composite containing different amount of silica filler, with different particle size, but with same amount of silanized silica and organic matrix showed similar flexural strength and flexural modulus except composite with lowest filler particle size , which showed lower flexural modulus.

Hahnel et al [15] in 2011 determined the two body wear resistance of modern direct dental restorative materials, nano, micro, hybrid, macrofilled composites, compomer, silorane, ormocer, a veneering composite and enamel were used for reference. Vickers hardness and inorganic filler weight were determined. Specimens were subjected to mastication simulation using a mastication simulator in a pin on block design, and concluded that similar wear behavior was found for silorane and ormocers based dental restorative materials.

MATERIALS AND METHODS

ARMAMENTARIUM AND EQIPMENTS

1. **Dry abrasion tester – Ducom TR -50 - Bangalore**
2. **Highly sensitive physical balance – Mettler devices (U.S.A)**
3. **Contact type surface profilometer – Time TR 100 (China)**
4. **Optical microscope – Meighi (Japan)**
5. **Scanning electron microscope - Hitachi - Japan**
6. **Ion sputter device- Hitachi - Japan**
7. **Custom made Stain less steel jig**
8. **Custom made Teflon instrument**
9. **Light curing unit - Dentsply**
10. **Distilled water**
11. **Glass slab**
12. **Acetate strips**

MATERIALS

Four posterior resin composite materials analyzed in the study, were ***FILTEK Z 350 XT*** (3M ESPE), ***FILTEK SILORANE P90*** (3M ESPE), ***ADMIRA*** (VOCO), and ***SUREFIL.*** **(**DENTSPLY)

The salient properties of these materials are mentioned below;

FILEK Z350XT (3M ESPE), Methacrylate based nano hybrid posterior composite

Filler type- silica nanofiller,zirconia/silica nanocluster

Average filler particle size-20-75 nano mm

Filler weight-78.5%

Filler volume-88 %

Resin matrix -*BISGMA, BISEMA, UDMA, TEGDMA AND PEGDMA.*

THE RESIN SYSTEM

Consists of three major components. The majority of TEGDMA was replaced with a blend of UDMA and Bis-EMA. UDMA and Bis-EMA resins are of higher molecular weight than TEGDMA and therefore have fewer double bonds per unit of weight. The high molecular weight materials also impact the measurable viscosity.

However, the higher molecular weight of the resin results in less shrinkage, improved aging and a slightly softer resin. TEGDMA and PEGDMA are used in minor amounts to adjust the viscosity. PEGDMA was used to replace part of the TEGDMA component to moderate shrinkage.

The sintering process was modified to produce loosely agglomerated nanoclusters. Although structurally different from densified particles, these nanoclusters behaved similarly to the densified particles found in other composites in terms of providing high filler loading. This resulted in a material with the strength and wear of hybrids with significantly improved polish retention and optical properties.

The restorative was formulated using both nano fillers and nanocluster fillers. The nanocluster consist of loosely bound aggregates of nanofiller particles. The addition of nanoparticles to formulations containing nanoclusters reduces the interstitial spacing of the filler particles leading to higher filler loadings. The filled matrix is harder and more wear resistant than resin alone. The increased filler loading results in better physical properties and wear resistance.

The nanoclusters comprised about 90% of the filler. Nanoclusters are produced in a broad range of sizes enabling a high filler loading. As the particles are not as strongly sintered, the cluster size range could be

broadened without affecting the properties such as polish retention. These nanoclusters still have the structural integrity to provide strength, fracture and wear resistance. During abrasion, the wear rate and wear pattern of the clusters is closer to that of the surrounding filled matrix.

FILTEK P-90 (3M ESPE) Silorane based micro hybrid posterior resin composite

Filler type - silanized quartz yttrium fluoride

Average filler particle size- 0.47 micron mm

Filler weight - 76 %

Filler volume - 86.6%

Resinmatrix-***3,4epoxycyclohexyl,ethylcyclopolymethylsiloxane,***

3,4 epoxycyclo hexylethyl-phenyl methyl silane

Improvements on the composite side were achieved, to a great extent, by optimizing the fillers – while the chemistry behind the organic resin matrix remained essentially the same since the pioneering work of R.L. Bowen in the 1960s. Practically all composites employ dimethacrylates such as TEGDMA, Bis-GMA or UDMA, which are radically polymerized as the primary resin monomer system.

The new low-shrinking restorative is based on the ring-opening silorane chemistry. The name silorane derives from its chemical building blocks *siloxanes* and *oxiranes*

In silorane-based resin composites, the *polymerization* starts with the initiation process of an acidic cation that opens the oxirane ring and generates a new carbocation subsequently, chain propagation and cross-linking occurs.

The new silorane based material has the ability to compensate shrinkage by opening the oxirane ring during polymerization, a photo initiated cationic polymerization which is insensitive to oxygen, as well as increased hydrophobicity due to the presence of siloxane species.

The *cationic polymerization initiation system* consists of three components: camphorquinone, an iodonium salt, and an electron donor. In the redox process, the electron donor decomposes the iodonium salt to an acidic cation which then starts the ring-opening polymerization process like the methacrylate-based composite, the silorane-based composite also contained camphorquinone so that current dental curing units can be used for polymerization

Filtek LS restorative is filled with a combination of fine quartz particles and radiopaque yttrium fluoride. The quartz surface is modified with a silane layer which was specifically matched to the silorane

technology in order to provide the proper interface of the filler to the resin for long-term, excellent mechanical properties.

ADMIRA (voco)

Filler type	-	Barium –aluminium –boro-silicate glass and silicon dioxide
Filler particle size	-	0.7 microns
Filler weight	-	77%
Filler volume	-	78%
Resin matrix	-	*Multi-functional urethane And thio ether acrylate alkoxysilanes as inorganic organic co polymers*

ORMOCER materials are synthesized by sol gel processing which yields inorganic organic units, that are organically functionalized inorganic organic hybrid polymers. They represent a class of materials that may be classified between polymers, silicones, and ceramics.

To synthesize the ormocer materials, inorganic oxidic units are established by hydrolysis and poly condensation reactions, starting with hydrolyzable functionalized silanes, the organic functionalities and the inorganic oxidic units are connected to form the inorganic–organic network by organic cross linking reactions.

Ormocers have a different matrix but share similar filler particles and a coupling mechanism with conventional resin composites.

SUREFIL (DENTSPLY)

Filler type	-	Ba- boron fluoride glass, silicon dioxide
Filler particle size	-	0.8 microns
Filler weight	-	77-82%
Filler volume	-	58-64%
Resin matrix	-	Urethane Modified Bis GMA

Packable composites also called as condensable composites, have been introduced as an alternative to amalgam. They are characterized by a high-filler load and a filler distribution that gives them a different consistency when compared with the hybrid composites.

Packable composites are used in stress bearing posterior restorations with the advantage of improved handling properties, lower technique sensitivity, exhibits superior physical and mechanical properties .The resin matrix also plays an important influence on the properties of the composite materials besides the filler system.

The resin matrix in packable composites is urethane dimethacrylate. This monomer is a brittle material with low viscosity.

The interaction of the filler particles and modifications of the resin cause these composites to be packable. Important properties include high depth of cure, low polymerization shrinkage, radiopacity, and low wear rate.

METHODOLOGY

The four posterior composites evaluated in the study were categorized as

GROUP 1 - FILTEKZ 350 XT.

GROUP 2 - FILTEK SILORANE P-90.

GROUP 3 - ADMIRA.

GROUP 4 - SUREFIL.

A custom jig was made with a square metal block of following dimensions- 25mm length, 25mm width and 4mm depth. The resin composite material was placed incrementally in 2mm depth using a custom made teflon instrument and polymerized according to the manufacturer's instruction .After the placement of second increment ,the mold spaces were covered with acetate strips, the composites restoratives were then light polymerized according to manufacturer's instructions. After light polymerization, the acetate strips were discarded. To avoid, discrepancies associated with rotary finishing and Polishing procedures, acetate strips was used for finishing composites. The samples were then stored in distilled water for 7 days. The specimens were subjected to three body wear test.

The wear instrumentation used was a Dry abrasion tester, (DUCOM TR 50 BANGALORE) customized with stainless steel wheel, and distilled water was used as lubricant. Test instrument was designed such that a flat test sample is pressed radially against a wheel with a force of 20N.

Abrasive media was introduced into the contact area between the sample under test and the wheel such that the wheel carries the abrasive media between the sample and the wheel creating a three body wear. The abraded material was collected in a chamber, positioned below the abrading wheel.

The intial weight of each specimen was measured in milligrams using a highly sensitive physical balance. (METTLER DEVICES) Material wear was measured by the loss of material at every 5000 cycles from 5000 cycles till 30000cycles.

The samples were evaluated for surface roughness at every 5000 cycles from 5000 cycles till 30000 cycles by using contact type surface profilometer. (TIME TR 100 CHINA) The standard parameters of the device includes a traversed length of 6mm , the sampling length was kept as 25 mm and the measuring scope of the device to evaluate Ra value was in the range of 0.05-10μm.

The mean weight loss was calculated from initial weight from 5000-30,000 cycles at an interval of every 5000 cycles and tabulated. The mean weight loss was calculated from previous weight and tabulated and subjected to statistical analysis.

The mean wear depth was calculated in mic.m from 5000-30000 cycles at an interval of every 5000 cycles and subjected to statistical analysis.

The wear surface was analyzed with optical microscope (MEIGHI JAPAN) and Scanning electron microscope (HITACHI) to characterize the wear pattern.

FLOW CHART

Four Posterior Composites were divided In to

Group-1 **Group-2** **Group-3** **Group-4**

Filtek Z-350 P-90 Admira Surefil

A Custom Made Stainless Steel Jig Was Made Of Following Dimensions 25mm Length, 25 Mm Width, 4mm Depth Resin Composites Were Condensed Incrementally In To The Jig And Cured

The Specimens Were Stored In Distilled Water for Seven Days

Specimens Were Subjected To Three Body Abrasive Wear Test

Weight Loss Was Estimated At 5000-30,000 Cycles

Surface Roughness was Evaluated At 5000-30,000 Cycles

Results Were Subjected to Statistical Analysis

The Wear Surface were examined and characterized with Optical Microscope and Scanning Electron Microscope

RESULTS

Wear was estimated by calculating the weight loss in milligrams from each samples with n (6) after 5000 cycles till 30,000 cycles at an interval of 5000 cycles. Datas were tabulated in (TABLE 1-4)

Wear depth was estimated by profilometer in micron meters represented as Ra values from each samples with n (6) after 5000 cycles till 30,000 cycles at an interval of 5000 cycles. Datas were tabulated in TABLES (5-8)

Mean and standard deviations were estimated from the samples with n (6) for each study group. The results of the present study was subjected to statistical analysis to interpret the significant differences in weight loss and Wear depth at various number of cycles between 5000-30000 cycles, within each group and also between the groups**.** One-Way ANOVA followed by Post Hoc Tuckey's test was used for statistical analysis in the present study.

One way analysis of variance (ANOVA) was used to study the overall variance within groups. It is the extension of the between groups t-test to the situation in which more than two groups are compared

simultaneously. It was not possible to identify the difference within the groups with the help of the P values obtained from ANOVA. Therefore a specific statistical test was used for intra-group comparison.

Tuckey's post hoc test was employed to do multiple comparison in between the group and within groups. All statistical analysis were done at the 0.05 significance level. SPSS version 16.0 was used to perform all statistical analysis.

In this study, one way ANOVA test showed a statistically significant difference among various groups due to the differences in weight loss before and after test with p value of 0.000 which denotes significance at 1% level and datas were tabulated in TABLE 9-10.

In the present study one way ANOVA showed statistically significance difference between the groups for wear depth, with p value of 0.000 which denotes significance at 1% level and datas were tabulated in TABLE (11)

Tuckey's post hoc test employed to identify the significance value showed statistically significance difference within the groups for weight loss and wear depth. And datas were tabulated in (TABLE-12-16)

To summarize the results

The inter group analysis showed

The mean weight loss values at the end of 30000 cycle was found to be highest in ***GROUP4*** and weight loss values was found to be lowest in ***GROUP 1*** **W**ith significance level of 1%.

The mean wear depth values at the end of 30000 cycle was found to be highest in ***GROUP4*** and lowest in ***GROUP1*** with a significance level of 1%

The intra group analysis showed

The mean weight loss values was found to be ***highest*** in all the groups at the end of 30000 cycles and the mean weight loss values was found to be ***lowest*** in all the groups at the end of at 5000 cycles with significance level of 1%.

The mean wear depth values was found to be ***highest*** in all the groups at the end of 30000 cycles and was found to be ***lowest*** at the end of 5000 cycles with a significance level of 1%

DISCUSSION

Wear resistance of composites as a posterior restoration is essential, for the longevity of restorations.[35] Wear of tooth structure and restorative materials may result from mechanical, physiological, or pathological conditions.[34] Wear is usually undesirable, and produces changes in shape that can affect function. In general, wear is a function of opposing materials and the interface between them. The presence of a lubricating film, such as saliva, separates surfaces during relative motion and reduces frictional forces and wear. The wear of composites as a function of composition has been evaluated extensively both in vitro and in vivo[7]

According to O Brien and yee wear of composites resin restoration results from following mechanism: Wear of the resin matrix, loss of filler through shearing of food, Loss of filler through cracking and failure of matrix and loss of filler by failure of its bond.[62]

Wear resistance of posterior composites has been evaluated extensively in longitudinal clinical studies. Results of these research have demonstrated that microfill composites are the most wear-resistant formulations.[67] Most commercially available restorative composites

(microfills, hybrids, packables) display extremely low in vitro and in vivo wear rates[67]

There are five types of composite wear events, based on the **location** of the restoration surface: wear by food (contact free area, or CFA wear), impact by tooth contact in centric (occlusal contact area, or OCA wear), sliding by tooth contact in function (functional contact area, or FCA wear), rubbing by tooth contact inter proximally (proximal contact area, or PCA wear), and wear from oral prophylaxis methods.[67]

Contact free area wear; This kind of wear forms appears in non-contact areas or contact free areas. The main responsible mechanism for this form is due to abrasive wear and chemical degradation. The wear at the CFA's mostly affects buccal and lingual grooves, which are the spill-ways for food abrasion. Although the resulted depth of the cavity is proposed to be about two to five times lower than the depth of the wear cavities in the occlusal contact areas, the generalized nature of the process often results in the replacement of the restoration[67].

CFA wear resistance of resin composites is not related to composites mechanical strength, but rather to filler spacing. Filler particles are much harder than the polymer matrix, and thus resist wear

very well. If filler particles are closely spaced, then they shelter the intervening matrix polymer -microprotection.[67]

Abrasive wear: It is the most common wear mechanism, and is generated when hard asperities plough into softer surfaces. These asperities may be an integral part of one surface. This type is known as 2-body abrasion and it occurs when there is a great dissimilarity in hardness between the two rubbing surfaces. It is proposed that the rough asperities under the applied normal load dig into the softer surface, and break loose as wear particles. The asperities may also be separate particle which are enmeshed between two surfaces, resulting in 3-body abrasion. Abrasion is proposed to be proportional to the hardness of the materials in contact, the geometry of the abrasive particles, the load and the sliding contact.[28]

Wear in the Occlusal and proximal Contact Areas; This kind of wear appears in contact and proximal points. The main responsible mechanism for this wear form is proposed to be the attrition caused by the repeated load cycling of chewing function. The pressure of chewing function is directly assigned from the antagonist to the restoration where it will be absorbed. The process results in deep but rather localized cavities on the contact points of a restoration. The action could possibly lead to the loss of occlusion height, which is of clinical value. Attrition

could also lead to loss of essential anatomic form and possibly to change in mastication efficiency.[67]

Functional contact area wear; It occurs by sliding tooth contact in function. There are three types of wear that occur with sliding motion namely abrasive, adhesive wear and fatigue wear [34]

Different approaches have been taken to relate physical properties such as fracture toughness to wear. Although some factors such as fracture toughness and the modulus of elasticity seem to be predictive for wear, they rely more on devices that simulate wear in vitro than on physical properties alone. [20]

Several research centre's developed wear testing devices of different degree of complexity.[29] Several two-body wear simulators have been designed and used with varying degree of success to imitate clinical wear which includes;

Two-body abrasion single-pass sliding, Two-body wear rotating counter sample , Taber Abraser , Two-body machine sliding wear , Pin-on-disk tribometer, Abrasive disk, Oscillatory wear test, Modified polisher (two-body), Fretting test, Oscillating friction and wear test .[29] Several variables need to be precisely described in order to be able to make comparative statements. Among them are force, frequency, number of cycles, lubricant, hardness, elastic modulus of the counter

body, running-in period, force of friction, force–displacement loop with coefficient of friction and dissipated energy. Because of a lack of information of these parameters, wear results are difficult to interpret in two-body wear machines.[29]

With three-body wear simulators, research centres are trying to mimic the oral environment and biological variables intending to rank restorative material according to their wear resistance in comparison to reference materials .Some of the three body wear simulators are ACTA wear machine , OHSU: Oregon Health Sciences University Oral Wear Simulator, University of Alabama Wear Simulator , Zurich computer-controlled masticator , BIOMAT wear simulator , Minnesota wear simulator, Willytec Munich and Muc wear simulator.[29]

It has been demonstrated that dental restorative materials show different wear mechanisms under different in vitro wear conditions [20], and that none of the existing wear devices can simulate the clinical wear process completely realistically.[19]

Also the clinical evaluation of wear is expensive and time consuming, and various important variables such as chewing forces or environmental factors cannot be controlled sufficiently. [20] Thus, despite the complexity of the clinical wear processes, laboratory mastication simulation allows the investigation of single parameters of the wear

processes, and the in vitro wear simulations also show considerable variability.[20]

Abrasion is an undesirable phenomenon, not only leading to an increase in surface roughness, but also resulting in the gradual removal of substance. Restoration roughness increases the coefficient of friction and may increase the rate of wear.[9]

Comparing 2 and 3-body abrasion reveals that abrasive particles involved in two body abrasion move forward and hit and scratch any object in front of their moving path. This is possible because 2-body abrasion particles are firmly attached to one of the surfaces. In 3- body abrasion particles however, change their sliding direction in an attempt to find the path of least resistance, and rotate and tumble in an attempt to reduce frictional resistance between the two surfaces.[42]

Consequently, 3-body abrasion targets the softer polymeric matrix of a composite, while two body abrasion cuts through both filler and matrix. It was suggested that the rate of material removal in 3-body abrasion can be only one order of magnitude lower than that for two body abrasion, because the loose abrasive particles abrade the solid surfaces between which they are situated only about 10 % of the time, while they spend about 90 % of the time rolling. Particle size, hardness and shape and volume fraction and distribution of the fillers, properties

of the matrix and the interfacial bonding are thought to influence the abrasive resistance of a composite Material.[42]

The aim of the present study was to evaluate the three body abrasive wear resistance of four different posterior resin composite, which have been recently introduced into the market, using Dry abrasion tester.

A three body abrasion test was done in this study because, ranking of composite restoration with three body abrasion tests simulated the clinical environment better than the two body abrasion tests.[61]

Three body abrasive wear has been considered the main wear mechanism active in contact-free areas, resulting in generalized loss of form.[28]

In the present study, the wear instrumentation used was a Dry abrasion tester, (DUCOM TR 50 BANGALORE) customized with stainless steel wheel, and distilled water was used as lubricant. Test instrument was designed such that a flat test sample is pressed radially against a wheel with a force of 20N. Abrasive media was introduced into the contact area between the sample under test and the wheel such that the wheel carries the abrasive media between the sample and the wheel creating a three body wear.[44]

The wear test has been carried out at 10rpm test speed. The tests were carried out at 20 N[12] loads by varying the abrading distance from 2.5 m to 15m silica was used as the abrasive. The abrasive was fed at the contacting face between the rotating wheel and the test sample. The rate of feeding the abrasive was kept as 255±5 g/min.[44]

The sample was cleaned with acetone and then dried. Its initial weight was determined with a high precision digital balance (0.1mg accuracy) before it was mounted in the sample holder. The abrasives were introduced between the test specimen and rotating abrasive wheel composed of stainless steel wheel. The diameter of the wheel used was 250 mm. The test specimen was pressed against the rotating wheel at a specified force of 20 N [15] by means of lever arm while a controlled flow of abrasives abrades the test surface.[44]

The rotation of the wheel was such that its contacting face moves in the direction of sand flow. The pivot axis of the lever arm lies within a plane, which was approximately tangent to the wheel surface and normal to the horizontal diameter along which the load was applied. At the end of a set test duration, the specimen was removed, thoroughly cleaned and again weighed (final weight). The difference in weight before and after abrasion was determined.[44]

In this study ***standardization*** of material was made such that all materials used were of shade A and the specimens were made with a square shaped jig having internal dimension of 25 mm length, 25mm width, 4mm depth ***according*** *to ASTMG 65* guidelines for abrasion testing.[44] In accordance to the study by **Yap et al**[60] to avoid discrepancies associated with rotary finishing and polishing procedures cellulose acetate strips were used to cover the specimens and glass slide was placed over the molds, to get a smooth finish.[60]

Based on the recommendations made by ***Yap*** **et al** [64], the composites were light polymerized according to manufacturers instruction, using a spectrum curing light .The mean intensity of the curing light was set in the unit as 450~ 10 mw/cm.^{2} Distilled water was chosen as the storage medium, one week period of storage time was recommended by **Yap et al** for post curing to occur and for the dissolution of all leachable filler components from the cured materials.[64]

In the present study, according to the recommendation made by **Condon** and **Ferracane** in 1997, the specimens were subjected to a maximum period of 30,000 cycles, an amount which procedures roughly the same amount of wear which occurs during six months of in vivo service.[7]

The other parameters in the present study was designed based on the reports of ***Yap et al*** a contact stress of 20 N was used as counter body for performing the abrasive wear test.[12] A stainless steel wheel was used, because enamel and enamel like antagonists tend to polish composite surfaces, producing little wear. Softer counter body materials like stainless steel are abraded by the inorganic fillers, producing a rough contact surface, which wears the composite matrix. Distilled water was used as lubricant, since it has been shown to produce greatest wear for most composite materials.[64]

In this study criteria for evaluating the wear of four posterior composites (Grouped as 1,2,3 and 4) were based on weight loss in milligrams and profilometric analysis to determine the wear depth (μm).

According to Yap, abrasive forces causes loss of material from the surface, so difference in weight was considered as the parameter to assess wear.[64]

According to the American Standard for Abrasion testing the amount of wear is determined by weighing the specimens before and after testing[44].

According to Teoah, abrasive forces causes a preferential loss of the resin phase during wear procedures. This will result in the filler

showing, in positive relief on the surface so, profilometric analysis were recorded to determine the wear depth. The present study simulated the abrasive wear conditions rather than attrition wear, because it is the main type of wear for posterior restorative materials.[62]

The results of this study showed that mean weight loss for Group -1 (Filtek z350)

after 5000 cycles was 27.83 mg,

after 10000 cycles was 5467 mg,

after 15,000 cycles was 82.5 mg,

after 20,000 cycles was 109.5 mg,

after 25,000 cycles was 139.17 mg

and at the end of 30,000 cycles was 166.67 mg which shows a steady increase in weight loss.

Group-2 (Filteksilorane p-90) had mean weight loss of

58.5 mg after 5,000 cycles,

114.17 mg after 10,000 cycles,

171.00mg after 15,000cycles ,

226.8 mg after 20,000 cycles,

281.67 mg after 25,000 cycles

and 340.0 mg at the end of 30,000 cycles ,which had a steady increase in weight loss.

Group-3 (Admira) had mean weight loss of

64.1 mg after 5,000 cycles,

127.7 mg after 10,000 cycles,

188.0 mg after 15,000cycles,

247.67 mg after 20,000 cycles,

310 mg after 25,000 cycles

and 376.9 mg at the end of 30,000 cycles ,which shows a steady increase in weight loss.

Group-4 (Surefill) had mean weight loss of

78.67mg after 5,000 cycles,

156.12 mg after 10,000 cycles,

230.0 mg after 15,000cycles,

307.0 mg after 20,000 cycles,

381 mg after 25,000 cycles

and 381.7 mg at the end of 30,000 cycles ,which shows a steady increase in weight loss.

The filler particle size for *Group-1 FILTEK Z 350 was 20 nm GROUP 2 P 90 was 0.47 (μm), GROUP -3 (ADMIRA) was0.7 (μm) ,GROUP 4 (SUREFIL) was 0.8 (μm)* .

In this study weight loss obtained as a measure of wear resistance, showed that group -1(filtek z 350) had the least amount of weight loss, Group-2 (p90) was the next best, followed by Group-3 (admira) Group-4 surefil showed maximum weight loss, at the end of every 5000 cycles till 30,00 cycles .

The weight loss obtained as a measure of wear resistance for the four composites at the end of 30,000 cycles were follows.

GROUP 1 (FILTEK Z 350) < GROUP 2 (P 90) < GROUP -3 (ADMIRA) < GROUP 4 (SUREFIL)

The results of this study showed, that decrease in filler particle size leads to decreased weight loss, which was also seen in a study by ***Lim et al***. [31]According to that study, dental composite containing larger

filler particles have good resistance to attrional wear, but have high abrasive wear rates, resulting in loss of anatomical form.[31]

According to **Nagarjan et al [41]** ***filler particle size has an major role on wear properties of dental composites.*** Previous studies showed that filler size plays an ***influencing*** factor in wear resistance of material.**[41]** High wear rates are related to larger fillers in composite materials. Similar results were seen in the present study even with micro and nano sized filler particles.

In this study it was seen that in two composites ***with different volume of fillers ,but almost same filler particle size had an influence on the amount of wear .***Although Group 3 (Admira) and Group 4 (surefil) with a particle size of 0.7 and 0.8 (μm)are nearly similar based on the filler particle size .The superior wear resistance for Group 3 (Admira) over Group 4 (Surefil) ***can be attributed to the higher filler volume ,w***hich is 78% in Group 3 (Admira) but only 58-66% in Group 4 (Surefil) .

Similar results were also observed in studies by ***Ferracane et al*** in 1997 and it was concluded that, ***filler volume on wear resistance follows a linear relationship.*** When volume is less than 48vol% the

larger expanses of resin are unprotected by filler particles does lead to higher wear rates.[12]

The results of the present study was in agreement with study by ***Clelland et al.*** in which they said that ***decreasing*** the particle size and increasing the percentage of filler volume, ***reduces the composite wear.***[6]

The filler volume % for *Group-1* ***FILTEKZ350*** *was 88%, GROUP 2* ***P90*** *was 86.5% , GROUP -3 (****ADMIRA****) was 78% GROUP 4 (****SUREFIL*** *) was 58%.*

The results of the present study showed that filler volume % followed a ***linear*** relationship on wear resistance. The GROUP I ***FILTEK*** Z ***350*** with 88% Filler volume had the least amount of weight loss, while GROUP 4 ***SUREFIL*** with 58% Filler volume had larger amount of weight loss.

According to Lamberechts **et al**[28] the difference in wear behavior can be attributed to different resin matrix chemistry which is also a key influencing factor in wear resistance.[28]

According to Manhart, **et al**[35] matrix in ormocer is characterized by an inter penetrating network of inorganic-organic copolymers, that is

formed through poly condensation and the filler particles are embedded in the cross linked inorganic –organic matrix.[35]

In the present study, Group-3 (Admira) an, ormocer based composite showed ***more*** amount of weight loss when compared with Group-2. Group 2 (P90) is an silorane based composite and showed least amount of weight loss, which can be attributed to silorane chemistry.

According to yap[60] in composites where the filler particles are ***harder*** than the matrix, the resin phase may suffer a preferential loss during abrasive wear procedures. This will result in the filler showing, in positive relief on the surface and also showed that the ability of wear procedure to abrade the filler influence the surface roughness .The larger filler particles had the high surface roughness and this was ***distinctly*** seen in the present study, which was clearly demonstrated by the surface profilometer.[60]

The results of the present study showed that the mean ***Ra*** value measured using profilometer for Group -1 (Filtek z350)

after 5000 cycles was 0.62 (μm),

after 10000 cycles was0.65 (μm),

after 15,000 cycles was 0.68 (μm),

after 20,000 cycles was 0.71 (μm)

after 25,000 cycles was 0.74 (μm)

and at the end of 30,000 cycles was 0.77 (μm) showing an ***steady*** increase in surface roughness.

Group-2 (Filteksilorane p-90) had mean Ra value of

0.71 (μm)after 5,000 cycles,

0.74 (μm) after 10,000 cycles,

0.78 (μm)after 15,000cycles ,

0.81 (μm) after 20,000 cycles,

0.84 (μm) after 25,000 cycles

and 0.88 (μm) at the end of 30,000 cycles ,showing an ***steady*** increase in surface roughness.

Group-3 (Admira) had mean Ra value of

0.83 (μm) after 5,000 cycles,

0.86 (μm) after 10,000 cycles,

0.9 (μm) after 15,000 cycles,

0.92 (μm) after 20,000 cycles,

0.95 (μm) after 25,000 cycles

and 0.95 (μm) at the end of 30,000 cycles , showing an ***steady*** increase in surface roughness.

Group-4 (Surefill) had mean Ra value of

0.9 (μm) after 5,000 cycles,

0.94 (μm) after 10,000 cycles,

0.97 (μm) after 15,000cycles,

1.02 (μm) after 20,000 cycles,

1.06 (μm) after 25,000 cycles

and 1.10 (μm) at the end of 30,000 cycles showing an ***steady*** increase in surface roughness.

The results of present study showed that ***Ra value measured was directly related to the filler particle size*** **.**With an increased filler particle size there was an increase in Ra value, which was due to the irregular surface created by the larger filler particles.

The filler particle size for *Group-1 FILTEK Z 350 was 20 nm GROUP 2 P 90 was 0.47 (μm), GROUP -3 (ADMIRA) was0.7 (μm),GROUP 4 (SUREFIL) was 0.8 (μm)*

When evaluated for surface roughness by the profilometer at every 5,000 cycles till 30,000 cycles, Group – 4 (surefil) which had the larger particle size and exhibited more surface roughness than the other groups. Group 3 (Admira) ranked next which had filler particle size of 0.7 (μm). Next to follow was Group -2 (P90) with filler particle size in range of 0.47 (μm), Group -1 (Filtek z350) which had least surface roughness due to the filler size of 20 nm.

The surface roughness obtained as a measure of wear resistance for the four composite at the end of 30,000 cycles showed that Ra values of

Group 1 (filtekz350) < Group 2 (P 90) < Group 3 (Admira) < Group 4 (Surefi)

This indicate that ***increase*** in filler particle size shows increased surface roughness, which was also seen in a study by ***Tagtekni et al*** [53] in which the composite with larger particle size exhibited higher surface roughness.

The results of the present study show ***no relevance between wear resistance and filler composition*** used in the composite. Group – 3 (ADMIRA), Group -4 (SURE FIL), had Barium, Boron, Aluminium as the ***common*** filler type, but ***had*** different wear resistance,when evaluated by weight loss and surface roughness. This could be related only to the filler particle's volume and size.

Other factors, including filler, filler shape and resin type may also play a part in three-body wear.But this could not be determined due to the unsystemic nature of the differences in composition between materials.[62]

In the present study ***Overall performance of Group -1 (FILTEK Z350)***A nano hybrid composite, which ***was best among the materials used in this study*** has a filler size of 5-20 nm and is 77% filled by volume. Filler particle clustering was thought to be one of the ***detrimental*** factors to the performance of nano filled particles that are arranged in clusters that approximate the size of individual filler particles of conventional hybrid composites.[67]

Lamberechts et al [28] showed that filler particles situated very closely protect the softer resin matrix from abrasive thus reduces wear[28]

Ferracane et al [12] showed that abrasion takes place through gradual removal of the resin matrix this eventually leaves the filler particles unsupported and susceptible to exfoliation.[12]

The results of the present study, has shown that Group -1 ***FILTEKZ350*** had ***lower*** loss of material and ***lower*** surface roughness values than other groups evaluated in this study, which was also seen in a study by ***Jorgenson's*** that composites "with small particles resist abrasion by ***protection mechanism*** in which thin expanses of resin are protected from abrasive forces by the presence of more closely spaced filler particles".[28]Nano composites ***due*** to ***modified*** filler technology have lesser material removal from the surface than from conventional hybrid composites.[45]

The Overall comparison between groups for weight loss revealed ***group1 (*****filtek z 35*****) showed the least weight loss followed by group2 (p90), group-3 (admira) and group4 (surefil)*** At the end of 30,000 wear cycles, with a gradual increase in weight loss for all the groups from 5000- to 30,000 cycles

AT ALL INTERVALS GROUP -1 FILTEK Z350 HAD THE LEAST WEIGHT LOSS AND GROUP-4 SUREFIL HAD THE MAXIMUM WEIGHT LOSS

The Overall comparison between materials for surface roughness with profilometer showed ***group4 (surefil)*** had more surface roughness followed by ***group3 (admira), group2 (p 90) and group 1 (filtek z 350)*** at the end of 30000 cycles, with a gradual increase in surface roughness for all the groups from 5000 to 30000 cycles.

AT ALL INTERVALS GROUP -1 FILTEK Z350 HAD THE LEAST Ra VALUE AND GROUP-4 SUREFIL HAD THE MAXIMUM Ra VALUE.

According to sarkar [62] wear, as a micromechanical surface interaction, cannot be observed directly. Wear has to be deducted from indirect evidence, such as wear rates, micro structural changes or wear debris type. Deductions were made in this study from the wear measurements and the micro structural features of the worn composite specimens using ***optical microscope and scanning electron microscope***.

The microstructure of the unworn areas and wear track area of the composites in all groups were analyzed seperately and a comparison was made between the SEM micrographs of wear tracks and unworn areas of the different composites.

The unworn area of the Group -1 showed the primary nano clusters and densely filled nanoparticles in the resin matrix. The worn area /wear track area after abrasion was found to be similar to the

nanofilled matrix surrounding the clusters, with less change in matrix and lesser filler exfoliation. The microstructure of wear track of Group-1 showed little difference in filler features and resin matrix composition from the unworn area.

The unworn area of the Group 2 showed the primary fillers particle are arranged uniformly in the in the resin matrix. The worn area /wear track area after abrasion was found to have slight change in resin matrix and minimal filler exfoliation was evident. The microstructure of wear track of Group -2 showed difference from the unworn area. With slight change in filler shape and less exfoliation of fillers. the resin matrix showed little change from unworn area.

The unworn area of the Group3 showed the uniform distribution primary fillers particle in the resin matrix. The worn area /wear track area after abrasion was found to have more change in resin matrix and filler exfoliation was evident. The resin matrix showed voids, crater shaped defect seen as black space and found to be different from unworn area.

The unworn area of the Group 4 showed the less uniform distribution primary fillers particle in the resin matrix. The worn area /wear tack area after abrasion was found to have gross change in resin matrix and filler exfoliation was more. The microstructure of the wear

track of Group 3 was different from the unworn area, with larger change in filler arrangement and exfoliation of fillers. The resin matrix showed deformation, voids, seen as vacant space and was found to be different from unworn area.

The wear performance of composites can be partially be explained by their microstructure of wear track area. In Group-1 the simultaneous loss of both phases, caused less changes, maintained a relatively smooth surface and lesser filler exfoliation due to their unique filler arrangement. protected the matrix from the wear which was evident from their micro structure, than the other Groups

Group-2 had less changes in the matrix from the wear which was evident from their relatively smooth micro structure and their unique matrix composition, had minimal filler exfoliation which can be attributed to the filler matrix interactions.

The microstructure of the wear track of Group-3 was different from that observed at the unworn areas. This can be attributed to the exposure of the pre polymerized filler complexes after wear testing. Exfoliation of the silica fillers was observed with Group-3

Large voids were observed, especially with Group -4 Surefil, and this can be associated with the exfoliation of the large barium fluoro alumino borosilicate glass particles that have a mean diameter of 5.2 μm. ***Filler***

displacement and ***micro cracking*** were more obvious around the large fillers in Group-4 than other groups.

The aim of the present study was to assess the ***loss of material in weight,*** which showed a relation to the filler particle size and volume and the matrix composition. The results indicated an ***decrease*** in wear resistance with an ***increase*** in filler particle size and ***increase*** in filler volume.

The results for wear analysis based on surface roughness using ***profilometry*** showed an increase in surface roughness with an increased filler particle size and Micro structural analysis through the SEM and Optical microscope ***confirmed*** the above findings and analyzed the changes, relation of the filler and matrix after the abrasion testing.

Wear tests in laboratories, are, therefore, desirable for the evaluation of wear behavior of dental materials under controlled and reproducible testing conditions. Many kinds of in-vitro wear experiments have been reported, including two-body and three-body abrasion tests.

Due to the different experimental designs and measuring systems, the results obtained in the laboratory simulation are not directly comparable, a possible way of comparison is to consider the ranking of

the tested materials in each study .Laboratory simulation is useful to study fundamental wear mechanisms but cannot predict clinical wear. Long-term clinical study though are difficult, time consuming, and has complex measuring procedures ***are*** still the most reliable method for abrasion wear studies. Research indicates that wear of current posterior resin composites when used in conservative preparations ranges from 2 to 10 microns per year The lower wear rates exhibited by current posterior resin composites compared to earlier resins are as a result of compositional changes made in the resins.

SUMMARY

Wear resistance of composite restorative materials has been a major concern especially when used as an posterior restorative material. The purpose of this study was to evaluate and compare the wear resistance of four newer posterior resin composites materials by three body wear simulation method. Wear was evaluated by measuring the amount weight loss using a highly sensitive physical balance, surface roughness was measured with a contact type surface profilometer and the wear surface characterized was by scanning electron microscope and optical microscope.

Four newer posterior resin composite materials used in the study was methacrylate based nanohybrid posterior composite filtek z350 (3M ESPE), a silorane based composite filtek silorane p90 (3M ESPE), Ormocer based composite admira (VOCO) and packable composite surefil (DENTSPLY). The four posterior composites evaluated in the study were categorized as, *group 1filtekz 350, group 2 - filtek silorane p-90 ,group 3 admira, group 4 surefil.* The wear instrumentation used was a Dry abrasion tester, customized with stainless steel wheel, and distilled water was used as lubricant. Test instrument was designed such that a flat test sample is pressed radially against a wheel with a force of

20N. Abrasive media was introduced into the contact area between the sample under test and the wheel such that the wheel carries the abrasive media between the sample and the wheel creating a three body wear.

The intial weight of each specimen was measured in milligrams using a highly sensitive physical balance. Material wear was measured by the loss of material at every 5000 cycles from 5000 cycles till 30000cycles.The samples were evaluated for surface roughness at every 5000 cycles from 5000 cycles till 30000 cycles by using contact type surface profilometer. The wear surface was analyzed with optical microscope and Scanning electron microscope to characterize the wear pattern. One-Way *ANOVA* followed by *TUCKEYS* post hoc test was used for statistical analysis at the 0.05 significance level

The mean weight loss values at the end of 30000 cycle was found to be highest in group 4 and weight loss values was found to be lowest in group1 with significance level of 1%.

The mean wear depth values at the end of 30000 cycle was found to be highest in group 4 and lowest in group 1 with a significance level of 1% and this findings were confirmed by scanning electron microscope findings.

CONCLUSION

From the results of the present study it can be concluded that**:**

1. Particle size plays a major role on the wear resistance of dental composites.

FILTEKZ-350 a nano hybrid composite with a filler particle size of 5-20nm revealed least weight loss at the end of 30000 cycles when compared with other newer posterior resin composites namely silorane, ormocers and packable composites used in this study

2 . An interesting observation made in the present study was that the percentage volume of filler revealed a linear relationship of the filler particles to the wear resistance of that material.

FILTEKZ350 with 88% filler volume had the least amount of weight loss when compared with other materials used in the study

3. Another valuable finding observed was the correlation between the filler particle size and the Ra, values that measures the wear depth. (in µm)

FILTEKZ350 with a filler particle size of 5-20 nm revealed a negligible ***Ra*** value of 0.77 μm at the end of 30000 cycles, when compared with other posterior resin composites used in this study

4. The scanning electron microscope and optical microscope findings of the wear surface at the end of 30,000 cycles for *FILTEKZ350* revealed a relatively, less filler exfoliation and changes in the matrix than the other materials and maintained a smooth surface.

Within the limitations of the present study, by correlating the values of mean weight loss, mean surface roughness, along with optical microscope and scanning electron microscope findings it can be concluded that.

5. ***FILTEKZ 350*** a nano hybrid composite material showed better wear resistance when compared with the other posterior resin composites evaluated in this study

From this investigative study it can be summarized that the clinical performance and longevity of a posterior resin composite could be enhanced by a scientific decision making in selection of the materials based on compositional factors such as filler particle size ,filler loading, color stability, wear resistance and polymerization shrinkage.

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FOUR GROUP OF POSTERIOR COMPOSITES EVALUTED IN THIS STUDY.

Fig.1

CUSTOM MADE SQUARE JIG

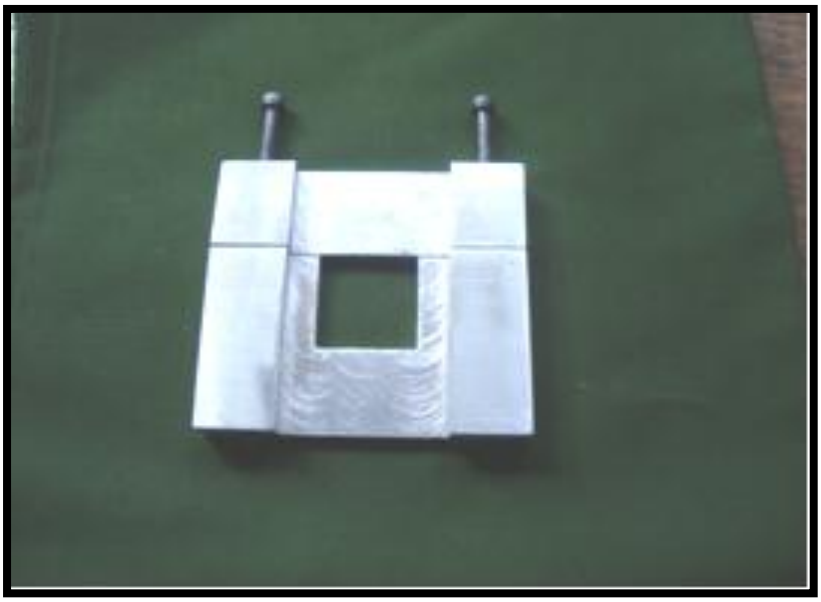


Fig.2

COMPOSITE CONDENSED INCREMENTALLY AND CURED

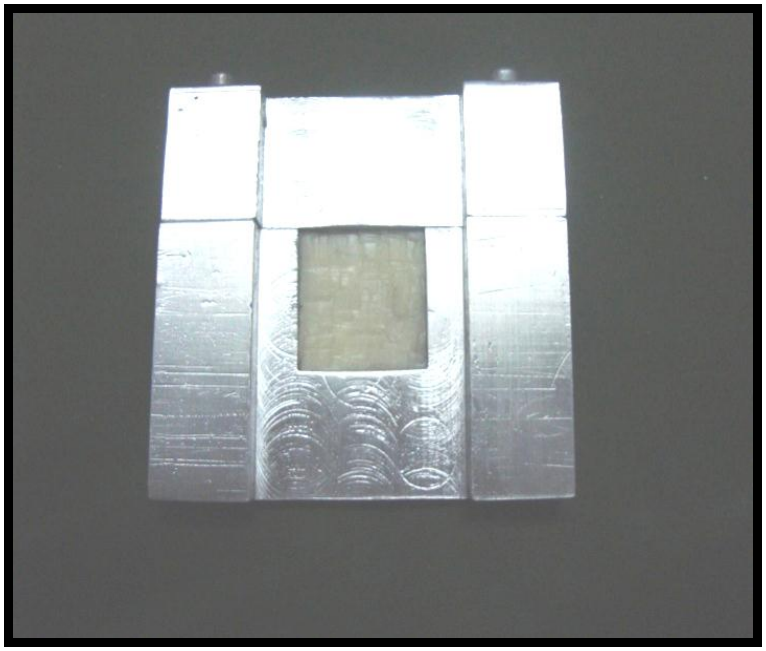


Fig.3

COMPOSITE REMOVED FROM THE JIG.

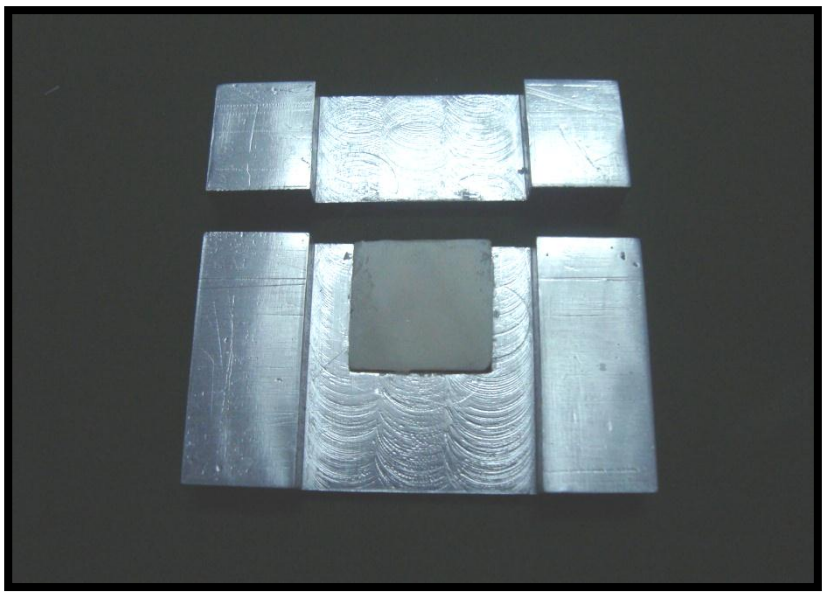


Fig.4

COMPOSIES STORED IN DISTILLED WATER

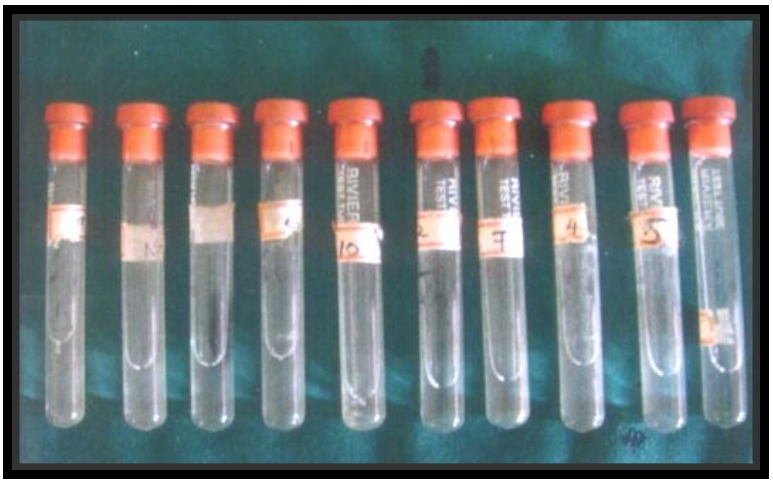


Fig.5

GROUP-1 FILTEK Z350

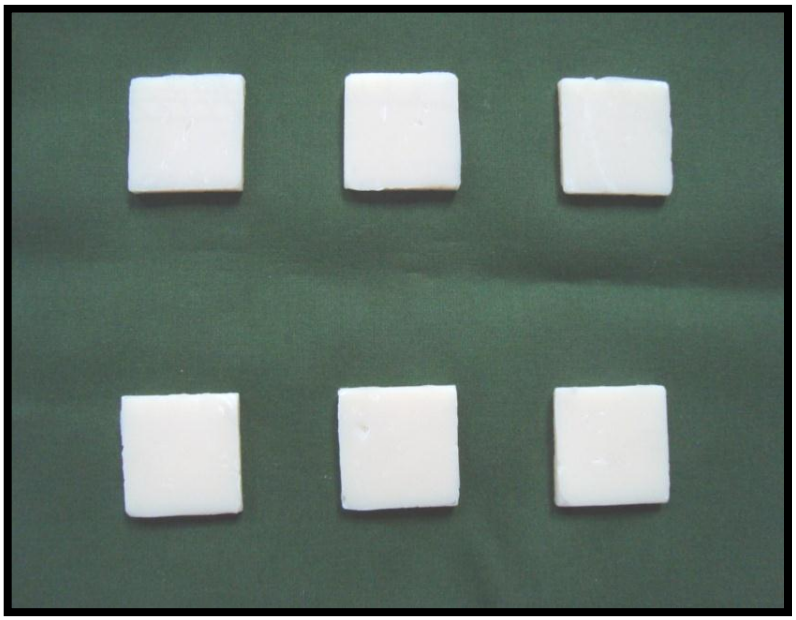


Fig.6

GROUP-2 FILTEK SILORANE

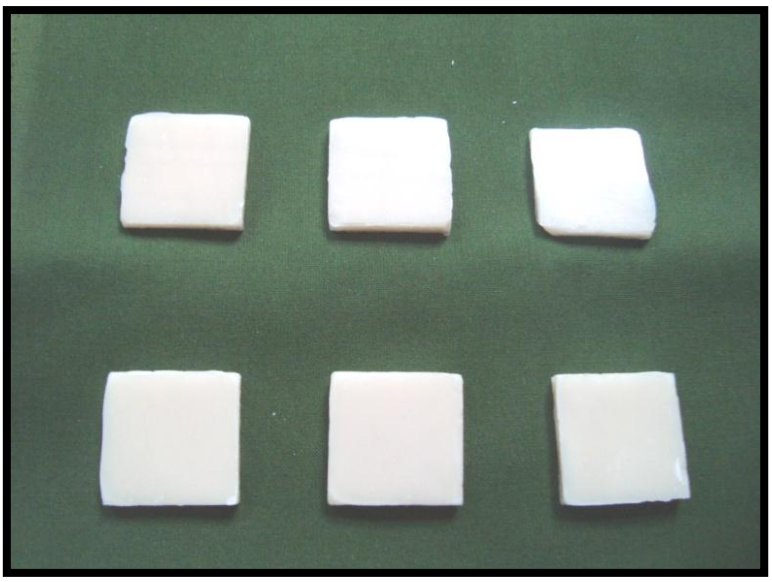


Fig.7

GROUP-3 ADMIRA

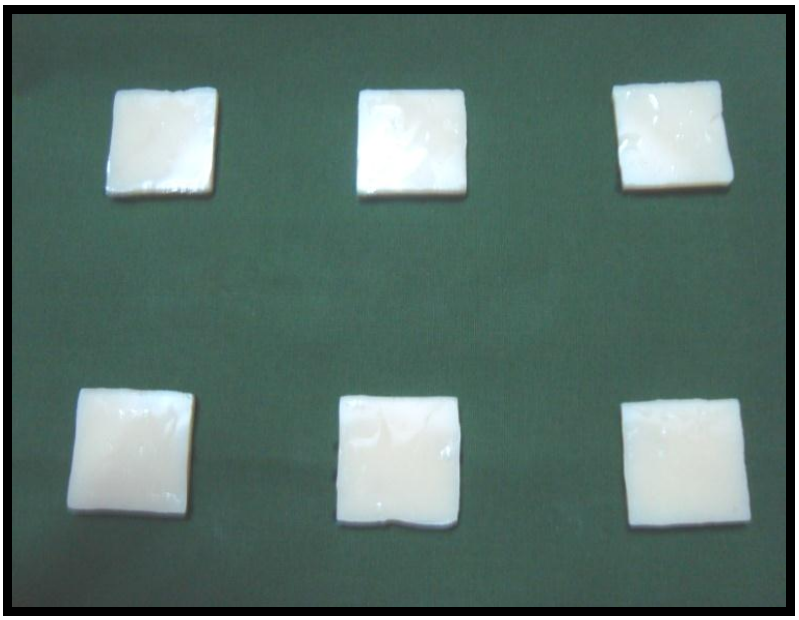


Fig.8

GROUP-4 SUREFIL

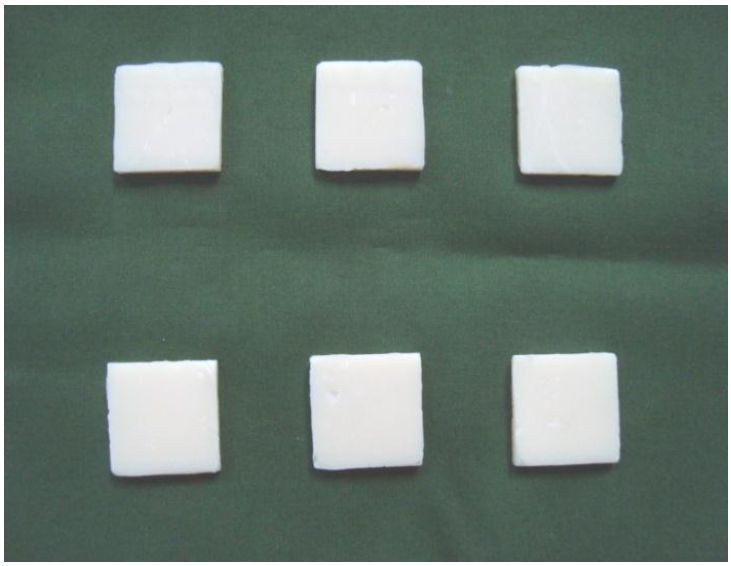


Fig.9

ABRASIVE WEAR TESTING EQUIPMENT-DUCOMTR-50

EXTERNAL VIEW

Fig.10

ABRASIVE WEAR CHAMBER

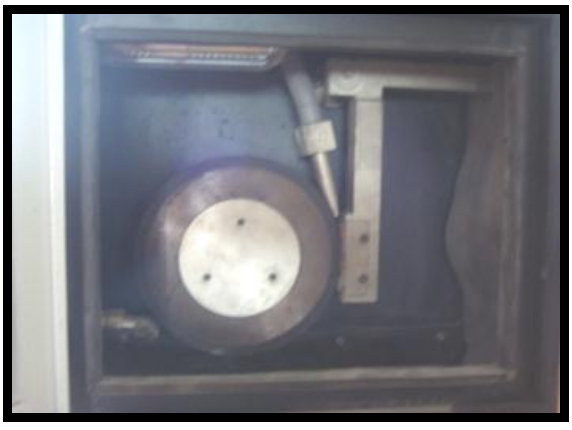


Fig.11

FIXER FOR HOLDING COMPOSITE IN THE

EQUIPMENT STRAIGHT VIEW

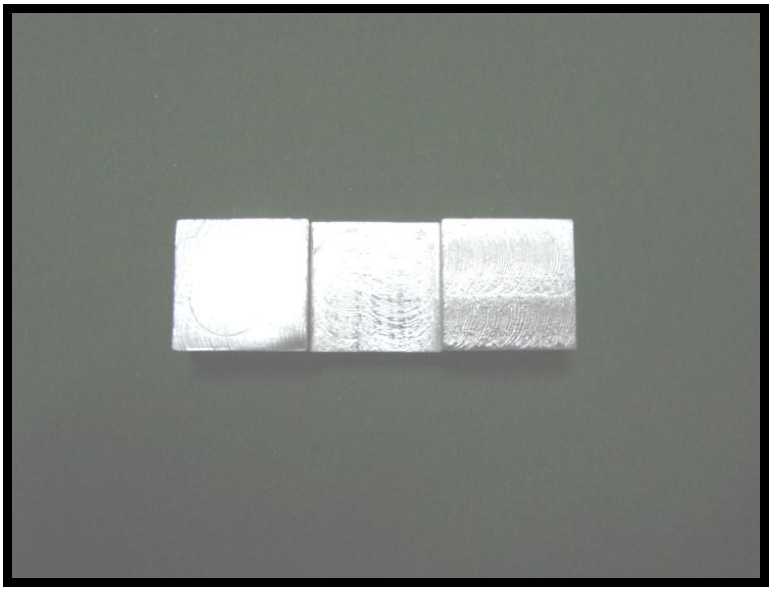


Fig.12

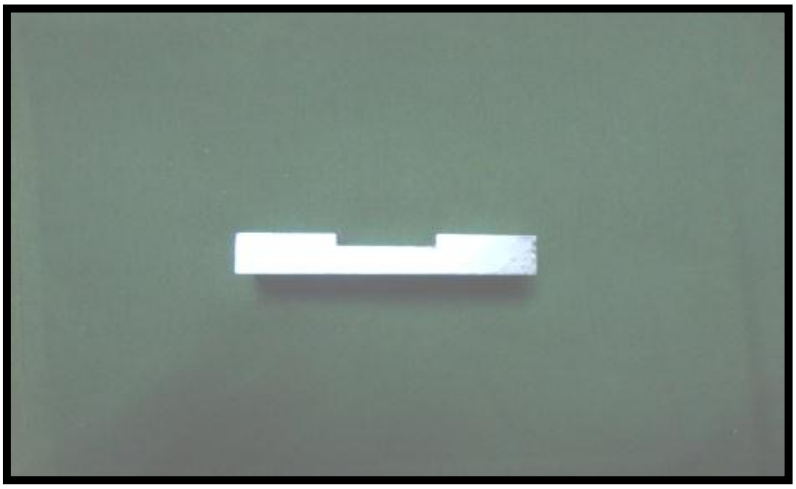


Fig.13

PHYSICAL BALANCE

Fig.14

PHYSICAL BALANCE WITH COMPOSITE SPECIMEN

Fig.15

CONTACT TYPE SURFACE PROFILOMETER-TIME TR 100

Fig.16

PROFILOMETER WITH – COMPOSITE SPECIMEN

Fig.17

OPTICAL MICROSCOPE MEIGHI JAPAN

Fig.18

ION SPUTTER-HITACHI

Fig.19

SAMPLE HOLDER

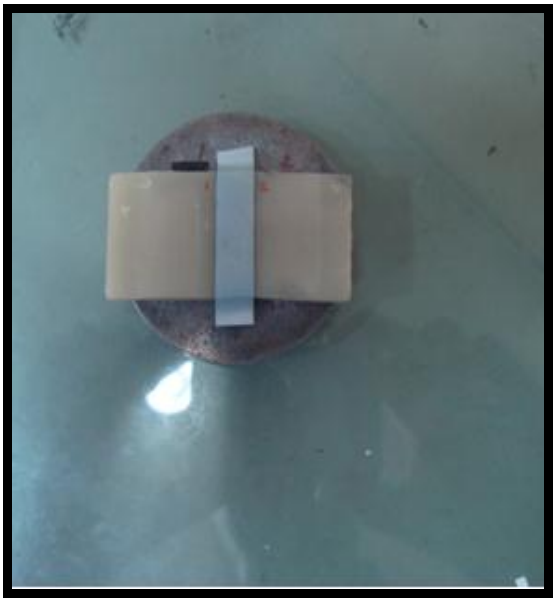


Fig.20

SCANNING ELCTRON MICROSCOPE HITACHI

Fig.21

OPTICAL MICROSCOPE PICTURES AT VARIOUS CYCLES -GR0UP-1

Fig.21a: BEFORE TEST

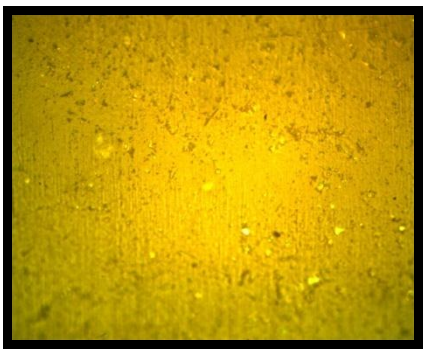


Fig.21b:AT THE END OF 5000 CYCLES

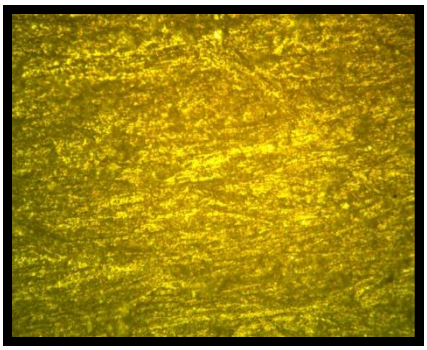


Fig.21c:AT THE END OF 10000 CYCLES

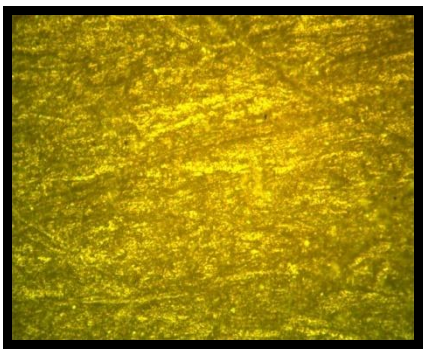


Fig.21d: AT THE END OF 15000 CYCLES

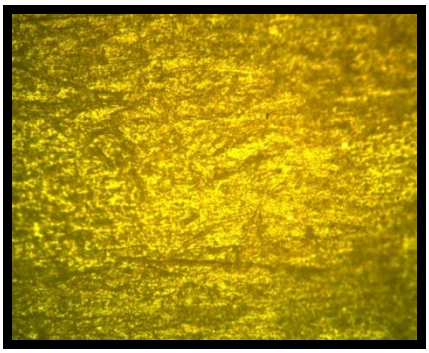


Fig.21e: AT THE END OF 20000 CYCLES

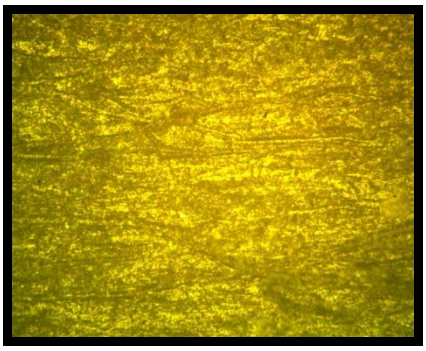


Fig. 21f: AT THE END OF 25000 CYCLES

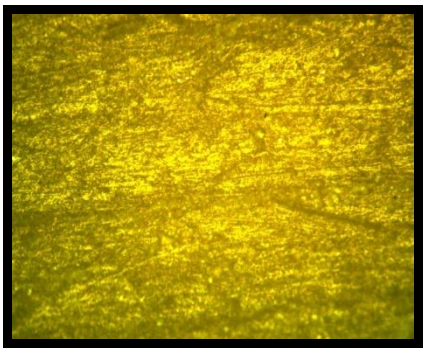
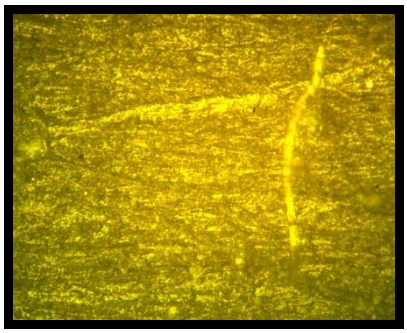


Fig. 21g: AT THE END OF 30000 CYCLES



OPTICAL MICROSCOPE PICTURES AT VARIOUS CYCLES -GR0UP-2

Fig. 22a: BEFORE TEST

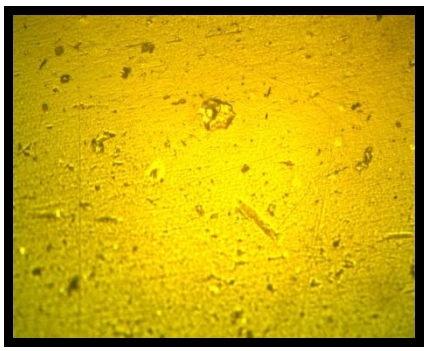


Fig. 22b: AT THE END OF 5000 CYCLES

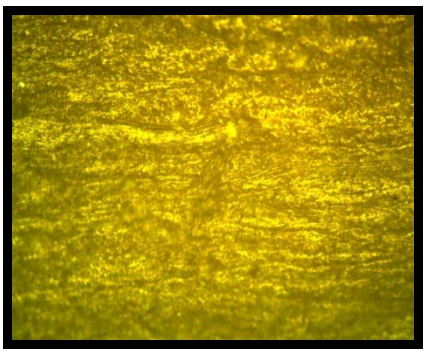


Fig. 22c: AT THE END OF 10000 CYCLES

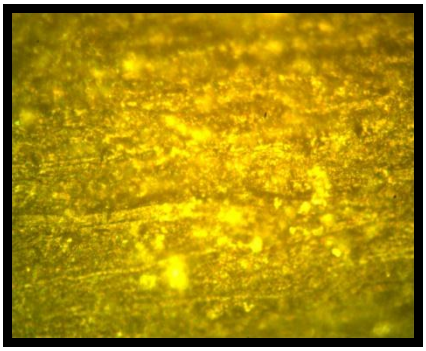


Fig. 22d: AT THE END OF 15000 CYCLES

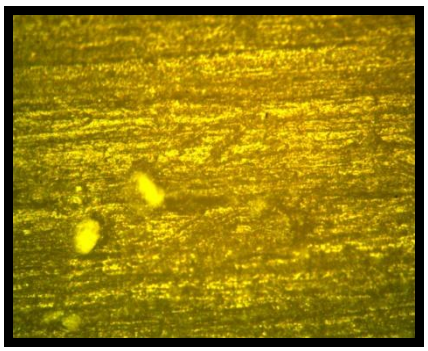


Fig.22e: AT THE END OF 20000 CYCLES

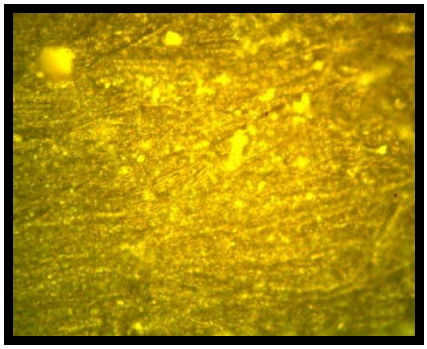


Fig. 22d: AT THE END OF 25000 CYCLES

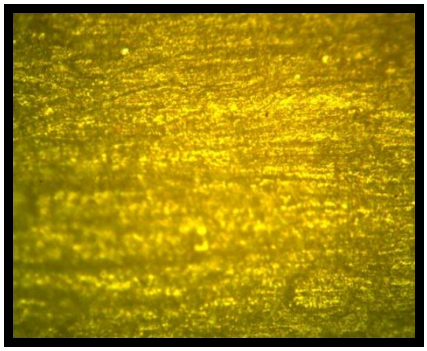
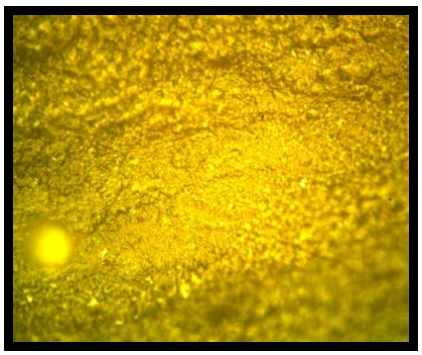


Fig. 22g: AT THE END OF 30000 CYCLES



OPTICAL MICROSCOPE PICTURES AT VARIOUS CYCLES - GROUP- 3

Fig.23a: BEFORE TEST

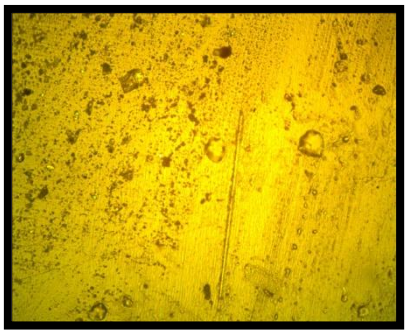


Fig. 23b: AT THE END OF 5000 CYCLES

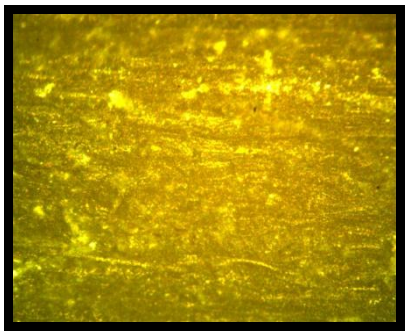


Fig. 23c: AT THE END OF 10000 CYCLES

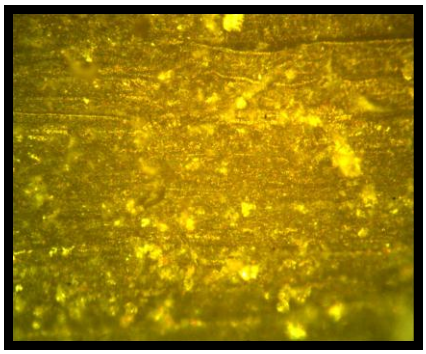


Fig. 23d:AT THE END OF 15000 CYCLES

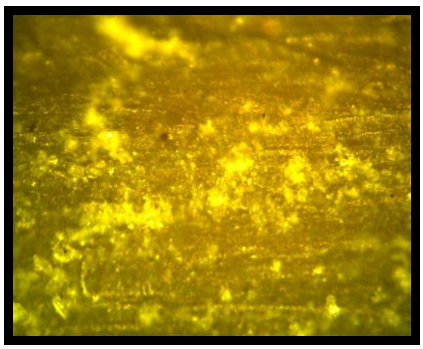


Fig. 23e: AT THE END OF 20000 CYCLES

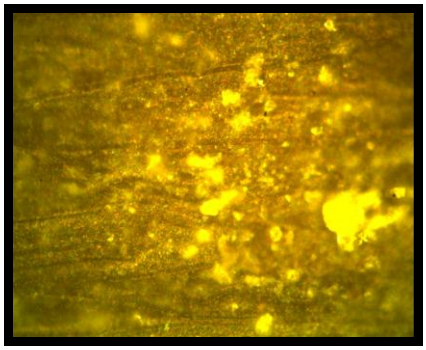


Fig. 23f:AT THE END OF 25000 CYCLES

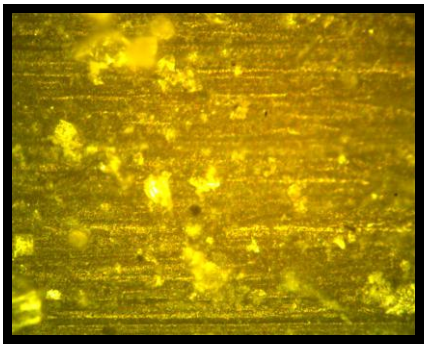
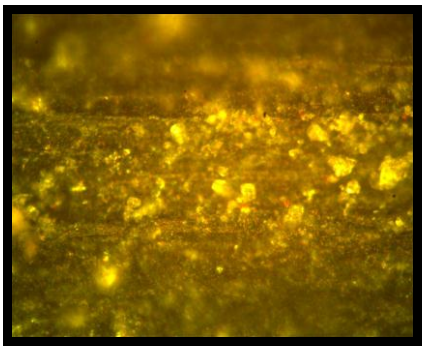


Fig. 23g: AT THE END OF 30000 CYCLES



OPTICAL MICROSCOPE PICTURES AT VARIOUS CYCLES -GR0UP-4

Fig. 24a:BEFORE TEST

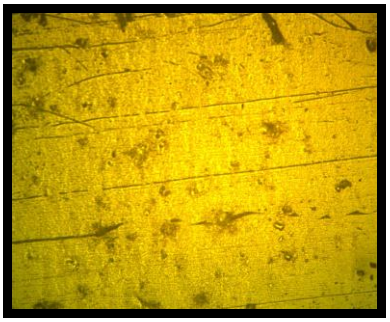


Fig.24b: AT THE END OF 5000 CYCLES

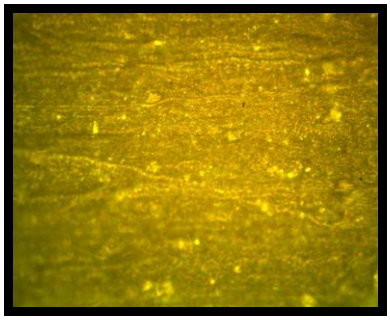


Fig. 24c: AT THE END OF 10000 CYCLES

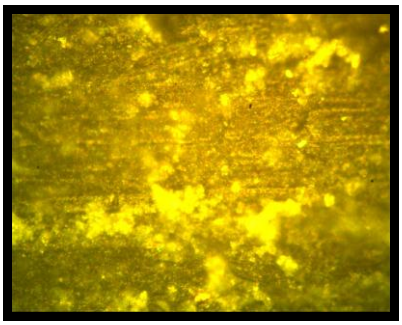


Fig. 24dAT THE END OF 15000 CYCLES

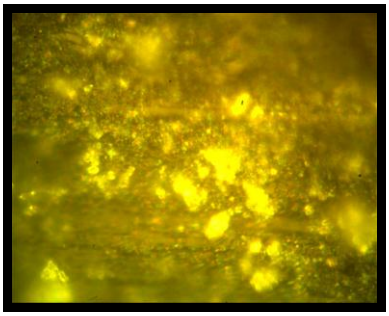


Fig. 24e:AT THE END OF 20000 CYCLES

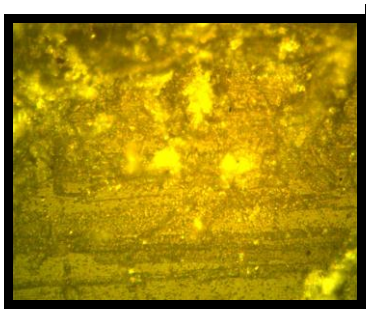


Fig. 24f: AT THE END OF 25000 CYCLES

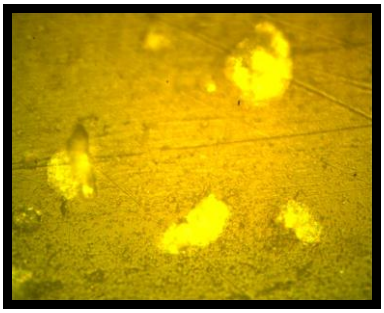
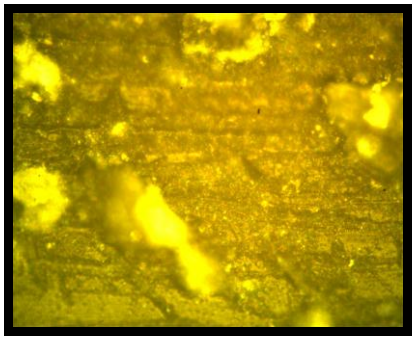
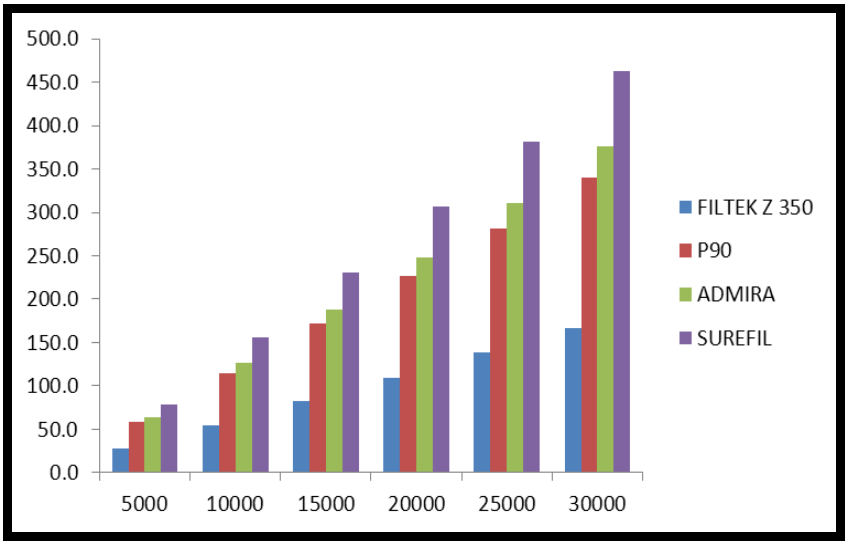


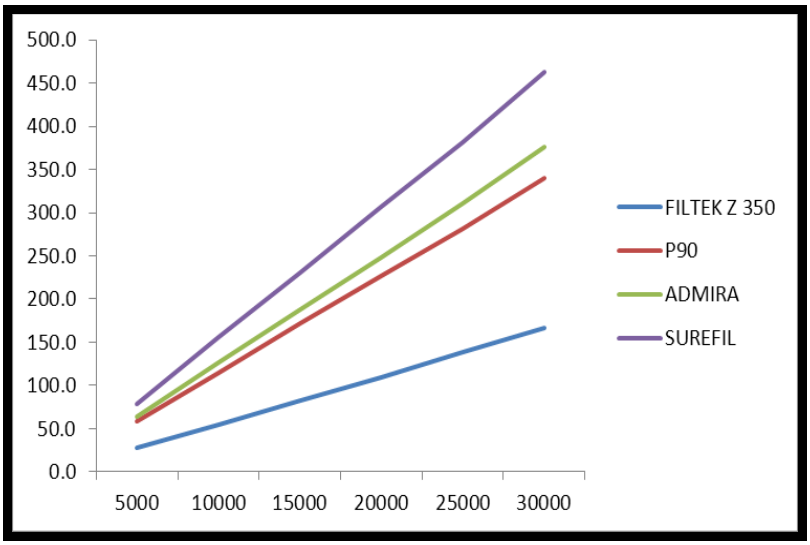
Fig. 24g: AT THE END OF 30000 CYCLES



GRAPH-1: ***COMPARISION OF MEAN WEIGHT LOSS IN MILLI GRAMS FROM INITIAL WEIGHT AT VARIOUS NUMBERS OF CYCLE S***

A. BAR GRAPH



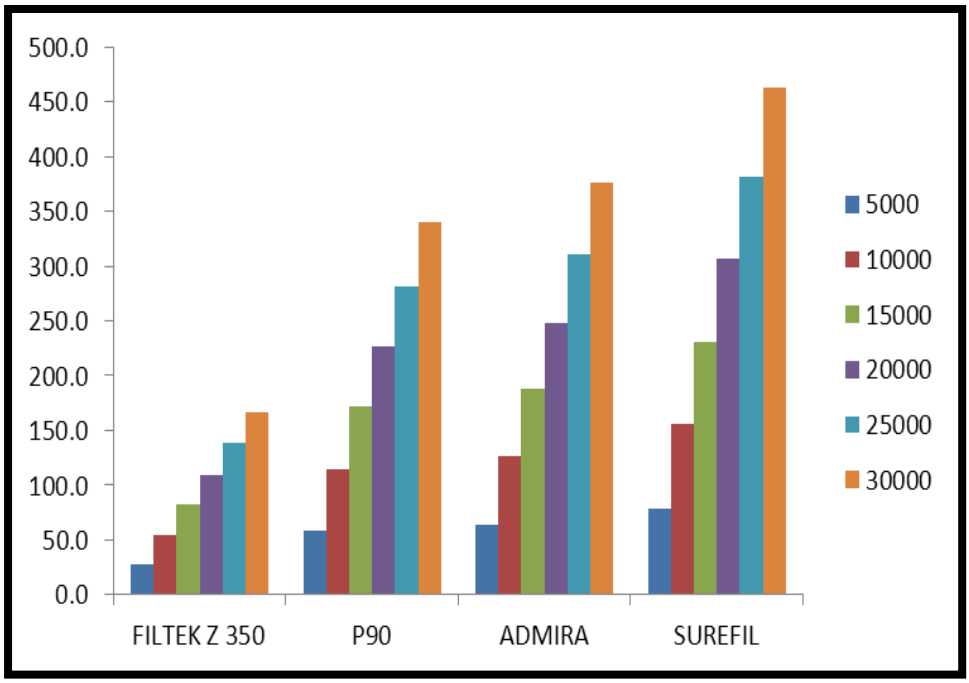


B. LINE GRAPH

X AXIS - NUMBER OF CYCLES Y AXIS - MEAN WEIGHT LOSS (mg)

GRAPH-2: ***COMPARISION OF MEAN WEIGHT LOSS IN MILLI GRAMS FROM INITIAL WEIGHT FOR EACH MATERIAL AT VARIOUS NUMBERS OF CYCLES***

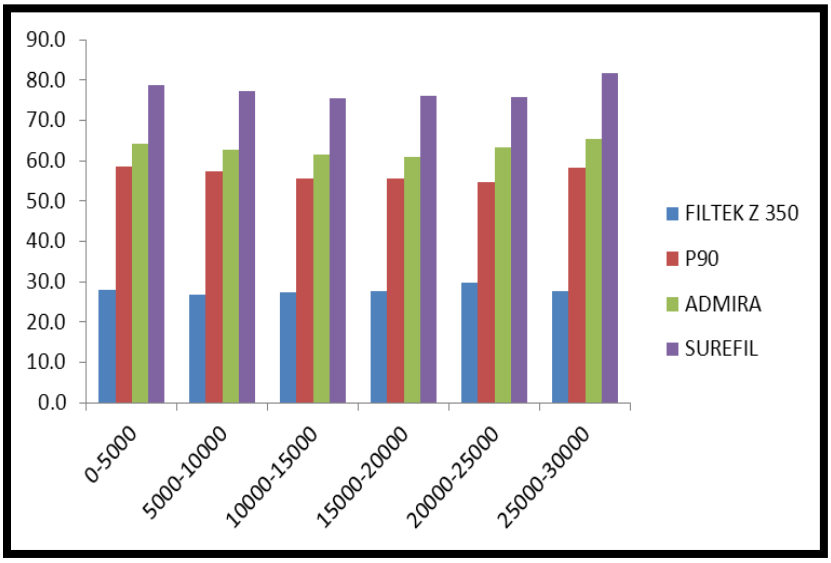
BARGRAPH

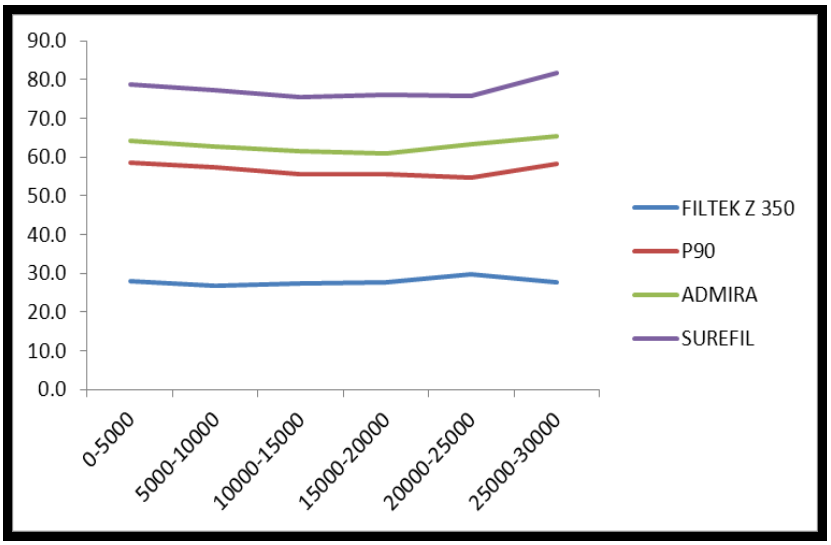


X AXIS - RESIN COMPOSITE RESTORATIVE MATERIALS
Y AXIS - MEAN WEIGHT LOSS (mg)

GRAPH 3: ***COMPARISION OF MEAN WEIGHT LOSS IN MILLI GRAMS FROM PREVIOUS WEIGHT (Inter value) AT VARIOUS NUMBERS OF CYCLES***

A. BAR GRAPH



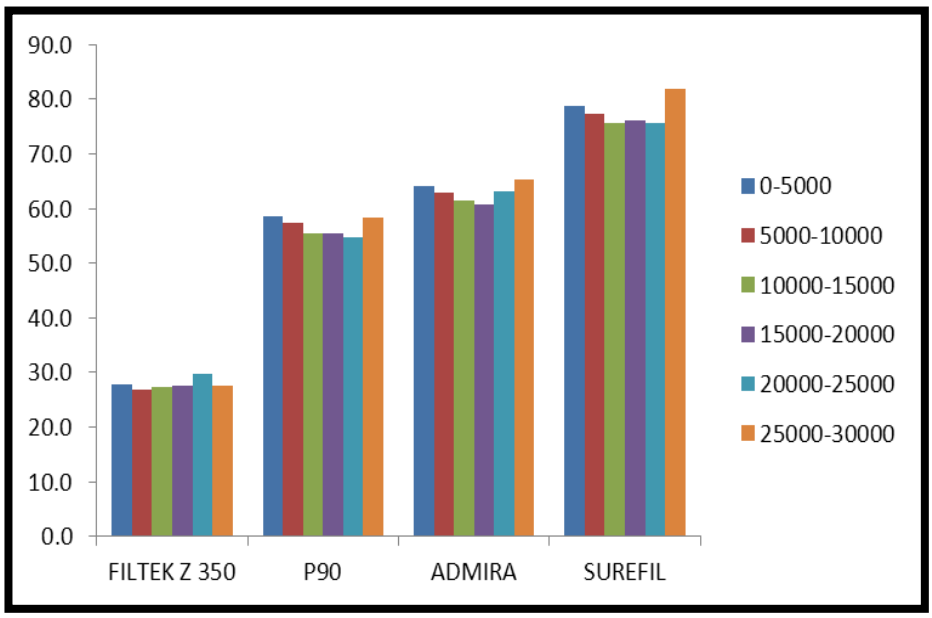


B. LINE GRAPH

X AXIS - NUMBER OF CYCLES Y AXIS - MEAN WEIGHT LOSS(mg)

GRAPH-4: ***COMPARISION OF MEAN WEIGHT LOSS IN MILLI GRAMS FROM PREVIOUS WEIGHT (Inter value) FOR EACH MATERIAL AT VARIOUS NUMBERS OF CYCLES***

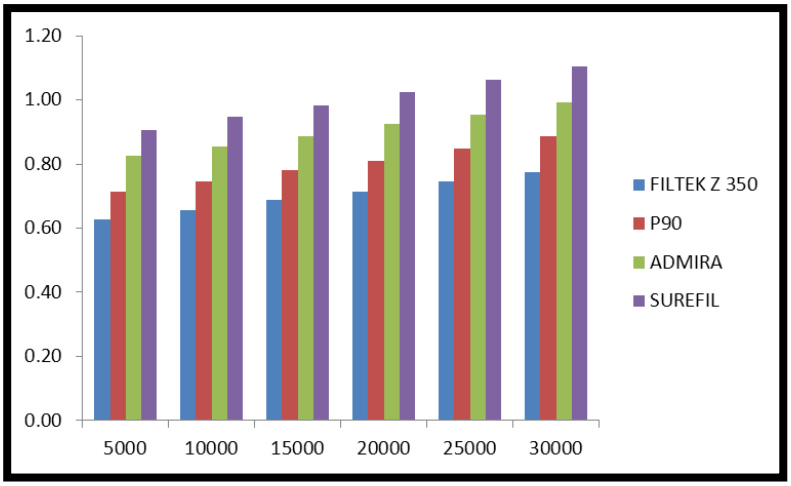
BAR GRAPH

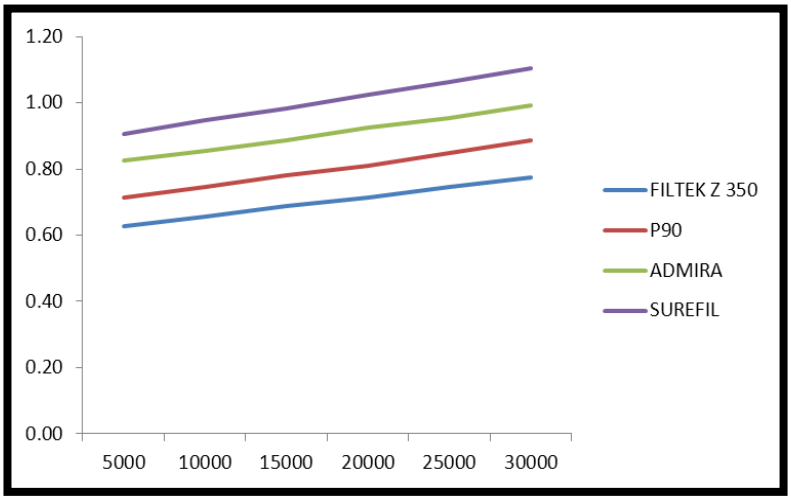


X AXIS - COMPOSITE RESTORATIVE MATERIALS
Y AXIS - MEAN WEIGHT LOSS (mg)

GRAPH 5: ***COMPARISION OF MEAN WEAR DEPTH (in*** **µ m)** ***AT VARIOUS NUMBERS OF CYCLES***

A. BAR GRAPH

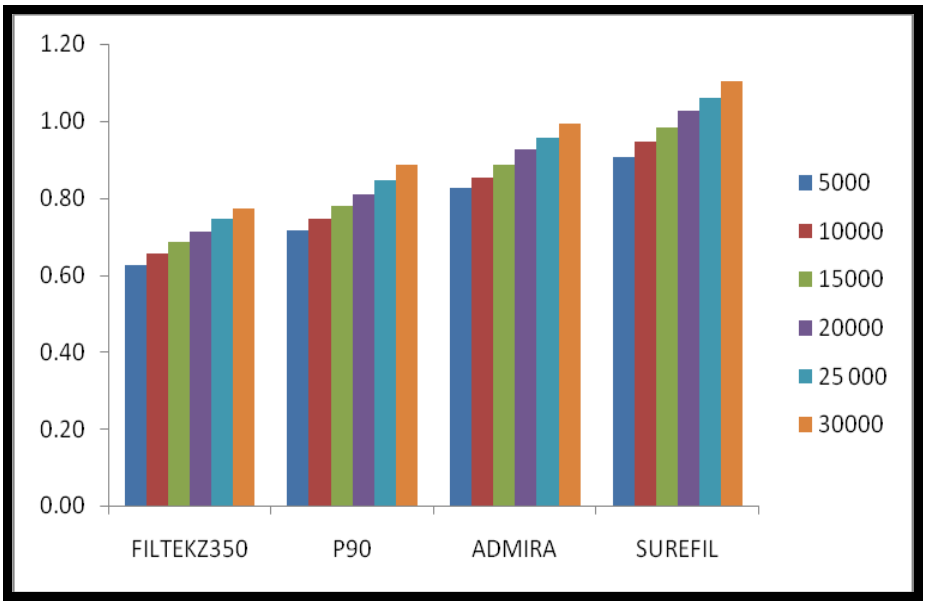




B. LINE GRAPH

X AXIS - NUMBER OF CYCLES Y AXIS - MEAN WEAR DEPTH(µ m)

GRAPH 6*: COMPARISION OF MEAN WEAR DEPTH (in* µ m)
FOR EACH MATERIAL AT VARIOUS NUMBERS OF CYCLES



X AXIS - COMPOSITE RESTORATIVE MATERAILS
Y AXIS - MEAN WEAR DEPTH (µ m)

SCANNING ELETRON MICROSCOPE IMAGE FOR GROUP -1

Fig.25a: IMAGE BEFORE WEAR TEST- (UN WORN AREA)

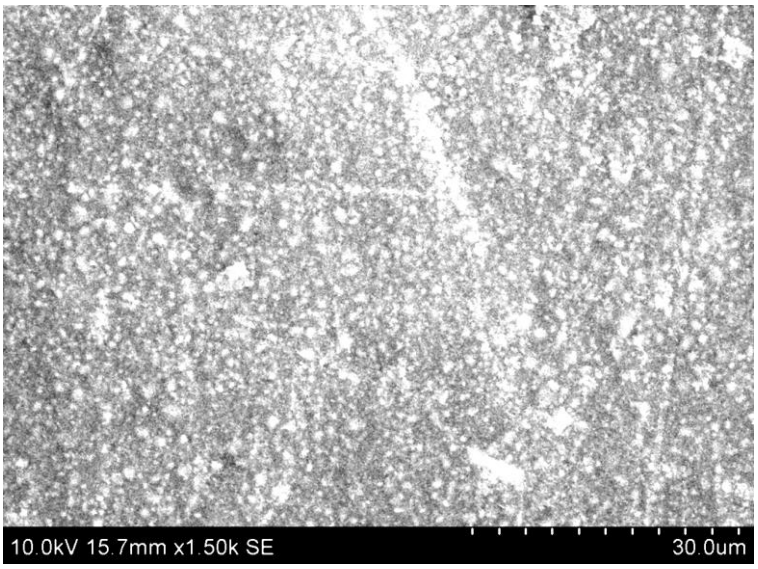
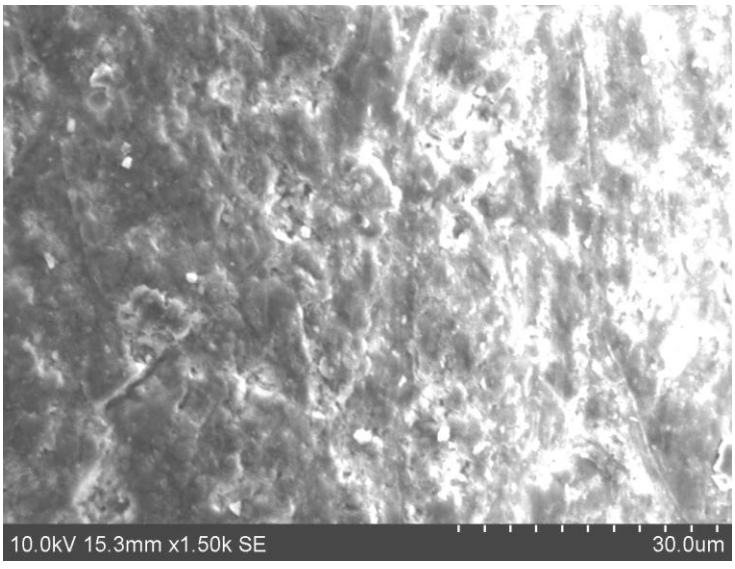


Fig.25b: AT THE END OF 30,000 CYCLES (WORN AREA)



SCANNING ELETRON MICROSCOPE IMAGE FOR GROUP2

Fig.26a: IMAGE BEFORE WEAR TEST- (UN WORN AREA)

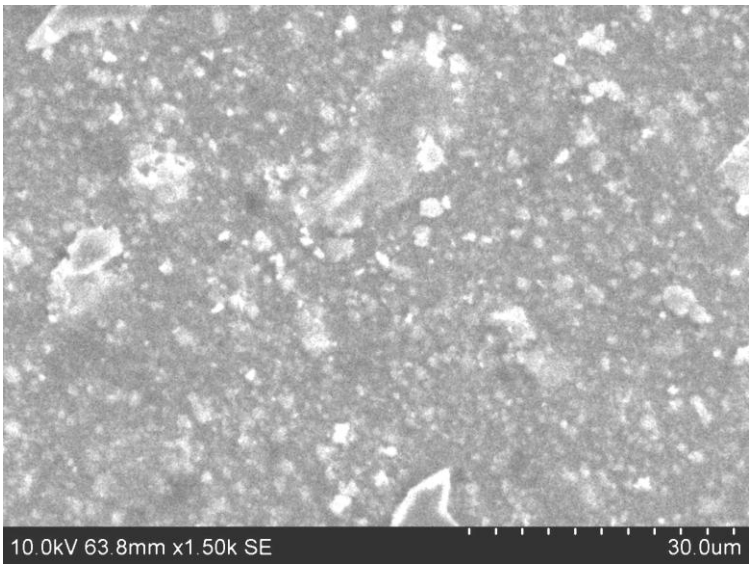
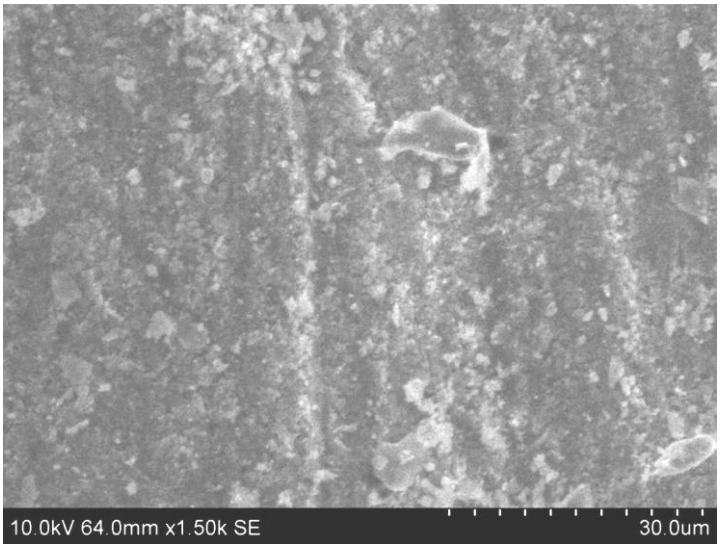


Fig.26b: AT THE END OF 30,000 CYCLES (WORN AREA)



SCANNING ELETRON MICROSCOPE IMAGE FOR GROUP3

Fig.27a: IMAGE BEFORE WEAR TEST- (UN WORN AREA)

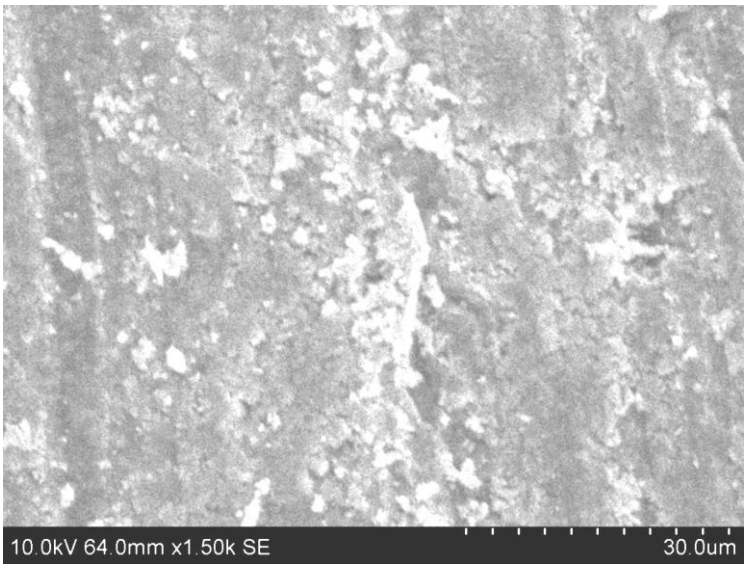
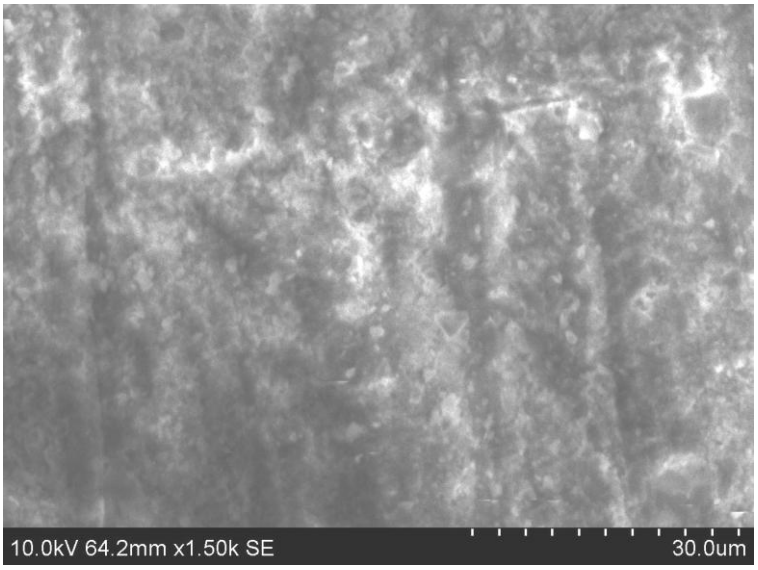


Fig.27b: AT THE END OF 30,000 CYCLES WORN AREA



SCANNING ELETRON MICROSCOPE IMAGE FOR GROUP4

Fig. 28a: IMAGE BEFORE WEAR TEST- (UN WORN AREA)

Fig.28b: AT THE END OF 30000 CYCLES WORN AREA

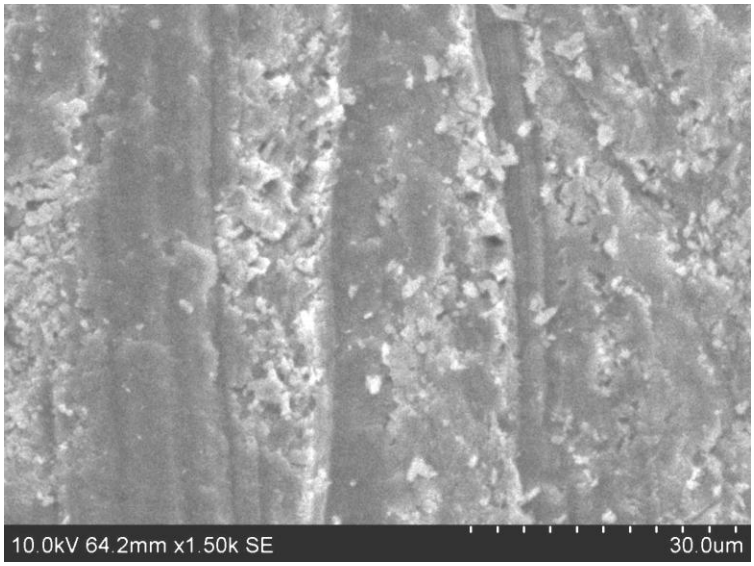


TABLE 1

DATAS FOR WEIGHT LOSS IN MILLIGRAMS AT VARIOUS NO.OF CYCLES FOR GROUP 1

SL.NO.	IW	WA5000 C	WL	IV	WA10000 C	WL	IV	WA15000 C	WL	IV	WA20000 C	WL	IV	WA25000 C	WL	IV	WA30000 C	WL
	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG
1	4194	4171	23	25	4146	48	23	4123	71	23	4100	94	33	4067	127	23	4044	150
2	3894	3863	31	29	3834	60	30	3804	90	31	3773	121	29	3744	150	30	3714	180
3	3924	3893	31	27	3866	58	29	3837	87	30	3807	117	37	3770	154	31	3739	185
4	3937	3911	26	27	3884	53	27	3857	80	27	3830	107	26	3804	133	25	3779	158
5	3839	3813	26	23	3790	49	25	3765	74	25	3740	99	24	3716	123	26	3690	149
6	4221	4191	30	30	4161	60	30	4131	90	29	4102	119	29	4073	148	30	4043	178

TABLE 2

DATAS FOR WEIGHT LOSS IN MILLIGRAMS AT VARIOUS NO.OF CYCLES FOR GROUP 2

SL.NO	IW	WA5000 C	WL	IV	WA10000 C	WL	IV	WA15000 C	WL	IV	WA20000 C	WL	IV	WA25000 C	WL	IV	WA30000 C	WL
	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG
1	3937	3882	55	55	3827	110	54	3773	164	54	3719	218	53	3666	271	55	3611	326
2	3911	3854	57	66	3788	123	46	3742	169	54	3688	223	54	3634	277	56	3578	333
3	3970	3906	64	61	3845	125	61	3784	186	60	3724	246	60	3664	306	63	3601	369
4	3865	3802	63	58	3754	111	61	3683	182	61	3622	243	60	3562	303	63	3499	366
5	4158	4099	59	53	4046	112	59	3987	171	52	3935	223	51	3884	274	60	3824	334
6	3861	3808	53	51	3757	104	52	3705	156	52	3653	208	51	3602	259	53	3549	312

IW : *Initial Weight* WA : *Weight After Test* IV : *Inter Value* C : *No. of Cycles*

TABLE 3

DATAS FOR WEIGHT LOSS IN MILLIGRAMS AT VARIOUS NO.OF CYCLES FOR GROUP 3

SL.NO.	IW	WA5000 C	WL	IV	WA10000 C	WL	IV	WA15000 C	WL	IV	WA20000 C	WL	IV	WA25000 C	WL	IV	WA30000 C	WL
	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG
1	3945	3889	56	61	3828	117	62	3766	179	62	3704	241	62	3642	303	61	3581	364
2	3868	3803	65	62	3741	127	60	3681	187	61	3620	248	61	3559	309	64	3495	373
3	3747	3678	69	68	3610	137	62	3548	199	63	3485	262	64	3421	326	69	3352	395
4	4062	3996	66	61	3935	127	63	3872	190	60	3812	250	64	3748	314	67	3681	381
5	3824	3756	68	63	3693	131	61	3632	192	61	3581	243	62	3519	305	70	3449	375
6	4129	4068	61	62	4006	123	61	3945	184	58	3887	242	66	3821	308	61	3760	369

TABLE 4

DATAS FOR WEIGHT LOSS IN MILLIGRAMS AT VARIOUS NO.OF CYCLES FOR GROUP 4

SL.NO.	IW	WA5000 C	WL	IV	WA10000 C	WL	IV	WA15000 C	WL	IV	WA20000 C	WL	IV	WA25000 C	WL	IV	WA30000 C	WL
	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG
1	4160	4082	78	74	4008	152	77	3931	229	71	3860	300	81	3789	371	78	3711	449
2	4496	4424	72	71	4353	143	67	4290	206	69	4221	275	72	4149	347	91	4058	438
3	4117	4041	76	75	3966	151	75	3891	226	81	3810	307	65	3745	372	76	3669	448
4	3986	3905	81	80	3825	161	81	3744	242	82	3662	324	81	3581	405	81	3500	486
5	4238	4153	85	83	4070	168	81	3989	249	82	3907	331	80	3827	411	85	3742	496
6	3904	3824	80	81	3743	161	72	3671	233	72	3599	305	75	3524	380	80	3444	460

IW : *Initial Weight* WA : *Weight After Test* IV : *Inter Value* C : *No. of Cycles*

TABLE 5

DATAS FOR WEAR DEPTH IN µ m AT VARIOUS NO. OF CYCLES FOR GROUP-1

SI NO	5,000 CY	10,000 CY	15,000 CY	20,000 CY	25,000 CY	30,000 CY
S1	0.65	0.67	0.7	0.72	0.75	0.78
S2	0.62	0.64	0.67	0.7	0.73	0.76
S3	0.64	0.67	0.69	0.71	0.74	0.77
S4	0.62	0.65	0.68	0.72	0.76	0.79
S5	0.59	0.62	0.67	0.7	0.73	0.76
S6	0.64	0.68	0.71	0.73	0.76	0.78

TABLE 6

DATAS FOR WEAR DEPTH IN µ m AT VARIOUS NO. OF CYCLES FOR GROUP-2

SA NO	5000 CY	10000 CY	15000 CY	20000 CY	25000 CY	30000 CY
S1	0.72	0.75	0.79	0.82	0.85	0.89
S2	0.74	0.77	0.81	0.84	0.87	0.9
S3	0.69	0.73	0.76	0.79	0.83	0.87
S4	0.75	0.78	0.81	0.84	0.88	0.91
S5	0.71	0.74	0.77	0.79	0.83	0.88
S6	0.68	0.71	0.74	0.78	0.82	0.86

TABLE 7

DATAS FOR WEAR DEPTH IN µ m AT VARIOUS NO. OF CYCLES FOR GROUP-3

SA NO	5000 CY	10000 CY	15000 CY	20000 CY	25000 CY	30000 CY
S1	0.81	0.83	0.86	0.9	0.93	0.97
S2	0.84	0.87	0.9	0.94	0.96	0.99
S3	0.78	0.81	0.84	0.88	0.92	0.96
S4	0.85	0.87	0.91	0.94	0.97	1.02
S5	0.82	0.85	0.89	0.93	0.96	0.99
S6	0.86	0.89	0.92	0.96	0.99	1.03

TABLE 8

DATAS FOR WEAR DEPTH IN µ m AT VARIOUS NO. OF CYCLES FOR GROUP4

SA NO	5000 CY	10000 CY	15000 CY	20000 CY	25000 CY	30000 CY
S1	0.89	0.93	0.97	1.01	1.04	1.09
S2	0.91	0.96	0.99	1.04	1.08	1.12
S3	0.94	0.98	1.02	1.05	1.09	1.13
S4	0.90	0.95	0.99	1.04	1.08	1.12
S5	0.92	0.94	0.98	1.02	1.05	1.09
S6	0.88	0.92	0.95	0.99	1.03	1.07

TABLE 9; MEAN WEIGHT LOSS IN MILLIGRAMS FROM INTIAL WEIGHT AT VARIOUS NUMBER OF CYCLES

MATERIALS		NUMBER OF CYCLES					
		5000	10000	15000	20000	25000	30000
GROUP-1 FILTEKZ350	MEAN	27.83	54.67	82.5	109.5	139.17	166.67
	SD	±3.312	±5.428	±8.270	±11.274	±13.13	±16.170
GROUP-2 FILTEK SILORANE	MEAN	58.5	114.17	171	226.83	281.67	340
	SD	±4.370	±8.134	±11.165	±14.770	±18.73	±22.724
GROUP-3 ADMIRA	MEAN	64.1	127.1	188	247.67	310.83	376.17
	SD	±4.875	±6.812	±6.892	±7.886	±8.329	±10.852
GROUP-4 SUREFIL	MEAN	78.67	156.I2	230	307	381	462.83
	SD	±4.457	±8.989	±14.851	±19.708	±23.723	±23.121
P VALUE	0.000 **	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

*** - DENOTES SIGNIFICANCE AT 5% CONFIDENCE LEVEL**

**** - DENOTES SIGNIFICANCE AT 1% CONFIDENCE LEVEL**

TABLE 10: MEAN WEIGHT LOSS IN MILLIGRAM FROM PREVIOUS WEIGHT AT VARIOUS NUMBER OF CYCLES (Inter value)

MATERIALS		NUMBER OF CYCLES					
		0-5000	5000 - 10000	10,000 - 15000	15000 - 20000	20,000 - 25000	25000 - 30000
GROUP-1 FILTEKZ350	MEAN	27.83	26.83	27.33	27.5	29.5	27.5
	SD	±3.312	±2.563	±2.875	±3.082	±4.719	±4.274
GROUP-2 FILTEK SILORANE	MEAN	58.5	57.33	55.5O	58.72	54.83	58.33
	SD	±4.370	±5.538	±5.958	±3.987	±4.167	±4.274
GROUP-3 ADMIRA	MEAN	64.1	62.83	61.58	66.8	63.17	65.33
	SD	±4.875	±2.639	±1.049	±1.722	±1.835	±3.933
GROUP-4 SUREFIL	MEAN	78.67	75.50	77.33	76.17	77.86	81.83
	SD	±4.457	±4.676	±5.431	±6.114	±6.377	±5.419
P VALUE	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

*** - DENOTES SIGNIFICANCE AT 5% CONFIDENCE LEVEL**

**** - DENOTES SIGNIFICANCE AT 1% CONFIDENCE LEVEL**

TABLE 11; MEAN DEPTH IN µm VALUE AT DIFFERENT NUMBER OF CYCLES

MATERIALS		NUMBER OF CYCLES					
		5000	10000	15000	20000	25000	30000
GROUP-1 FILTEKZ350	MEAN	0.6267	0.6550	0.687	0.7133	0.7450	0.7733
	SD	±0.02160	±0.02258	±0.0163	±0.01211	±0.01378	±0.01211
GROUP-2 FILTEK SILORANE	MEAN	0.7150	0.7467	0.780	0.8100	0.8467	0.8850
	SD	±0.02739	±0.02582	±0.0283	±0.02683	±0.02422	±0.01871
GROUP-3 ADMIRA	MEAN	0.8267	0.8533	0.887	0.9250	0.9550	0.9933
	SD	±0.02944	±0.02944	±0.0308	±0.02950	±0.02588	±0.02733
GROUP-4 SUREFIL	MEAN	0.9067	0.9467	0.983	1.0250	1.0617	1.1033
	SD	±0.02160	±0.02160	±0.0234	±0.02258	±0.02483	±0.02338
P VALUE	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

*** - DENOTES SIGNIFICANCE AT 5% CONFIDENCE LEVEL**

**** - DENOTES SIGNIFICANCE AT 1% CONFIDENCE LEVEL**

TABLE -12 POST HOC TUKEYS TEST VALUES FOR COMPARISION OF MEAN WEIGHT LOSS* FROM INTIAL WEIGHT *BETWEEN VARIOUS GROUPS

MATERIALS		5000 C	10000C	15000C	20000C	25000 C	30000C
GROUP-1	*MEAN*	27.83	54.67	82.5	109.5	139.17	166.67
	S.D	±3.312	±5.428	±8.270	±11.274	±13.13	±16.170
GROUP-2	*MEAN*	58.5	114.17	171	226.83	281.67	340
	S.D	±4.370	±8.134	±11.165	±14.770	±18.73	±22.724
P VALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP -1	*MEAN*	27.83	54.67	82.5	109.5	139.17	166.67
	S.D	±3.312	±5.428	±8.270	±11.274	±13.13	±16.170
GROUP-3	*MEAN*	64.1	127.1	188	247.67	310.83	376.17
	S.D	±4.875	±6.812	±6.892	±7.886	±8.329	±10.852
P VALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-1	*MEAN*	27.83	54.67	82.5	109.5	139.17	166.67
	S.D	±3.312	±5.428	±8.270	±11.274	±13.13	±16.170
GROUP-4	*MEAN*	78.67	156.I2	230	307	381	462.83
	S.D	±4.457	±8.989	±14.851	±19.708	±23.723	±23.121
PVALUE		0.000 **	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-2	*MEAN*	58.5	114.17	171	226.83	281.67	340
	S.D	±4.370	±8.134	±11.165	±14.770	±18.73	±22.724
GROUP-3	*MEAN*	64.1	127.1	188	247.67	310.83	376.17
	S.D	±4.875	±6.812	±6.892	±7.886	±8.329	±10.852
PVALUE		0.2	0.045	0.071	0.112	0.045	0.021
GROUP-2	*MEAN*	58.5	114.17	171	226.83	281.67	340
	S.D	±4.370	±8.134	±11.165	±14.770	±18.73	±22.724
GROUP-4	*MEAN*	78.67	156.I2	230	307	381	462.83
	S.D	±4.457	±8.989	±14.851	±19.708	±23.723	±23.121
PVALUE	*0.000 ** *	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-3	*MEAN*	64.1	127.1	188	247.67	310.83	376.17
	S.D	±4.875	±6.812	±6.892	±7.886	±8.329	±10.852
GROUP-4	*MEAN*	78.67	156.I2	230	307	381	462.83
	S.D	±4.457	±8.989	±14.851	±19.708	±23.723	±23.121
PVALUE	*0.000 ** *	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

*** - DENOTES SIGNIFICANCE AT 5% CONFIDENCE LEVEL** - DENOTES SIGNIFICANCE AT 1% CONFIDENCE LEVEL**

TABLE -13 POST HOC TUKEYS TEST VALUES FOR COMPARISION OF MEAN WEIGHT LOSS FROM PREVIOUS WEIGHT BETWEEN VARIOUS GROUPS

MATERIALS		0-5000C	5000-10000C	10000-15000C	15000-20000C	20000-25000C	25000-30000C
GROUP-1	*MEAN*	27.83	26.83	27.33	27.5	29.5	27.5
	S.D	±3.312	±2.563	±2.875	±3.082	±4.719	±4.274
GROUP-2	*MEAN*	58.5	57.33	55.5O	58.72	54.83	58.33
	S.D	±4.370	±5.538	±5.958	±3.987	±4.167	±4.274
P VALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP -1	*MEAN*	27.83	26.83	27.33	27.5	29.5	27.5
	S.D	±3.312	±2.563	±2.875	±3.082	±4.719	±4.274
GROUP-3	*MEAN*	64.1	62.83	61.58	66.8	63.17	65.33
	S.D	±4.875	±2.639	±1.049	±1.722	±1.835	±3.933
P VALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-1	*MEAN*	27.83	26.83	27.33	27.5	29.5	27.5
	S.D	±3.312	±2.563	±2.875	±3.082	±4.719	±4.274
GROUP-4	*MEAN*	78.67	75.5	77.33	76.17	77.86	81.83
	S.D	±4.457	±4.676	±5.431	±6.114	±6.377	±5.419
PVALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-2	*MEAN*	58.5	57.33	55.5O	58.72	54.83	58.33
	S.D	±4.370	±5.538	±5.958	±3.987	±4.167	±4.274
GROUP-3	*MEAN*	64.1	62.83	61.58	66.8	63.17	65.33
	S.D	±4.875	±2.639	±1.049	±1.722	±1.835	±3.933
PVALUE		0.177	0.154	0.203	0.03	0.063	0.01
GROUP-2	*MEAN*	58.5	57.33	55.5O	58.72	54.83	58.33
	S.D	±4.370	±5.538	±5.958	±3.987	±4.167	±4.274
GROUP-4	*MEAN*	78.67	75.5	77.33	76.17	77.86	81.83
	S.D	±4.457	±4.676	±5.431	±6.114	±6.377	±5.419
PVALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-3	*MEAN*	64.1	62.83	61.58	66.8	63.17	65.33
	S.D	±4.875	±2.639	±1.049	±1.722	±1.835	±3.933
GROUP-4	*MEAN*	78.67	75.5	77.33	76.17	77.86	81.83
	S.D	±4.457	±4.676	±5.431	±6.114	±6.377	±5.419
PVALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

*** - DENOTES SIGNIFICANCE AT 5% CONFIDENCE LEVEL**

**** - DENOTES SIGNIFICANCE AT 1% CONFIDENCE LEVEL**

TABLE -14 POST HOC TUKEYS TEST VALUES FOR COMPARISION OF MEAN WEAR DEPTH BETWEEN VARIOUS GROUPS

MATERIALS		5000 C	10000C	15000C	20000C	25000 C	30000C
GROUP-1	*MEAN*	0.6267	0.655	0.687	0.7133	0.745	0.7733
	S.D	±0.02160	±0.02258	±0.0163	±0.01211	±0.01378	±0.01211
GROUP-2	*MEAN*	0.715	0.7467	0.78	0.81	0.8467	0.885
	S.D	±0.02739	±0.02582	±0.0283	±0.02683	±0.02422	±0.01871
P VALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP -1	*MEAN*	0.6267	0.655	0.687	0.7133	0.745	0.7733
	S.D	±0.02160	±0.02258	±0.0163	±0.01211	±0.01378	±0.01211
GROUP-3	*MEAN*	0.8267	0.8533	0.887	0.925	0.955	0.9933
	S.D	±0.02944	±0.02944	±0.0308	±0.02950	±0.02588	±0.02733
P VALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-1	*MEAN*	0.6267	0.655	0.687	0.7133	0.745	0.7733
	S.D	±0.02160	±0.02258	±0.0163	±0.01211	±0.01378	±0.01211
GROUP-4	*MEAN*	0.9067	0.9467	0.983	1.025	1.0617	1.1033
	S.D	±0.02160	±0.02160	±0.0234	±0.02258	±0.02483	±0.02338
PVALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-2	*MEAN*	0.715	0.7467	0.78	0.81	0.8467	0.885
	S.D	±0.02739	±0.02582	±0.0283	±0.02683	±0.02422	±0.01871
GROUP-3	*MEAN*	0.8267	0.8533	0.887	0.925	0.955	0.9933
	S.D	±0.02944	±0.02944	±0.0308	±0.02950	±0.02588	±0.02733
PVALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-2	*MEAN*	0.715	0.7467	0.78	0.81	0.8467	0.885
	S.D	±0.02739	±0.02582	±0.0283	±0.02683	±0.02422	±0.01871
GROUP-4	*MEAN*	0.9067	0.9467	0.983	1.025	1.0617	1.1033
	S.D	±0.02160	±0.02160	±0.0234	±0.02258	±0.02483	±0.02338
PVALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
GROUP-3	*MEAN*	0.8267	0.8533	0.887	0.925	0.955	0.9933
	S.D	±0.02944	±0.02944	±0.0308	±0.02950	±0.02588	±0.02733
GROUP-4	*MEAN*	0.9067	0.9467	0.983	1.025	1.0617	1.1033
	S.D	±0.02160	±0.02160	±0.0234	±0.02258	±0.02483	±0.02338
PVALUE		0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

*** - DENOTES SIGNIFICANCE AT 5% CONFIDENCE LEVEL**

**** - DENOTES SIGNIFICANCE AT 1% CONFIDENCE LEVEL**

TABLE -15 POST HOC TUKEYS TEST VALUES FOR COMPARISION OF MEAN WEIGHT LOSS WITIN THE GROUP FOR DIFFERENT NUMBER OF CYCLES.

NUMBER OF CYCES		GROUP1	GROUP2	GROUP3	GROUP4
5000	*MEAN*	27.83	58.5	64.1	78.67
	S.D	±3.312	±4.370	±4.875	±4.457
10000	*MEAN*	54.67	114.17	127.1	156.I2
	S.D	±5.428	±8.134	±6.812	±8.989
PVALUE		0.002	0.000**	0.000**	0.000**
5000	*MEAN*	27.83	58.5	64.1	78.67
	S.D	±3.312	±4.370	±4.875	±4.457
15000	*MEAN*	82.5	171	188	230
	S.D	±8.270	±11.165	±6.892	±14.851
PVALUE		0.000**	0.000**	0.000**	0.000**
5000	*MEAN*	27.83	58.5	64.1	78.67
	S.D	±3.312	±4.370	±4.875	±4.457
20000	*MEAN*	109.5	226.83	247.67	307
	S.D	±11.274	±14.770	±7.886	±19.708
PVALUE		0.000**	0.000**	0.000**	0.000**
5000	*MEAN*	27.83	58.5	64.1	78.67
	S.D	±3.312	±4.370	±4.875	±4.457
25000	*MEAN*	139.17	281.67	310.83	381
	S.D	±13.13	±18.73	±8.329	±23.723
PVALUE		0.000**	0.000**	0.000**	0.000**
5000	*MEAN*	27.83	58.5	64.1	78.67
	S.D	±3.312	±4.370	±4.875	±4.457
30000	*MEAN*	166.67	340	376.17	462.83
	S.D	±16.170	±22.724	±10.852	±23.121
PVALUE		0.000**	0.000**	0.000**	0.000**

*** - DENOTES SIGNIFICANCE AT 5% CONFIDENCE LEVEL** - DENOTES SIGNIFICANCE AT 1% CONFIDENCE LEVEL**

TABLE -16 POST HOC TUKEYS TEST VALUES FOR COMPARISION OF MEAN WEAR DEPTH WITIN THE GROUP AT VARIOUS CYCLES

NUMBER OF CYCES		GROUP1	GROUP2	GROUP3	GROUP4
5000	*MEAN*	0.6267	0.715	0.8267	0.9067
	S.D	±0.02160	±0.02739	±0.02944	±0.02160
10000	*MEAN*	0.655	0.7467	0.8533	0.9467
	S.D	±0.02258	±0.02582	±0.02944	±0.02160
PVALUE		0.106	0.585	1	0.076
5000	*MEAN*	0.6267	0.715	0.8267	0.9067
	S.D	±0.02160	±0.02739	±0.02944	±0.02160
15000	*MEAN*	0.687	0.78	0.887	0.983
	S.D	±0.0163	±0.0283	±0.0308	±0.0234
PVALUE		0.000**	0.002	0.000**	0.000**
5000	*MEAN*	0.6267	0.715	0.8267	0.9067
	S.D	±0.02160	±0.02739	±0.02944	±0.02160
20000	*MEAN*	0.7133	0.81	0.925	1.025
	S.D	±0.01211	±0.02683	±0.02950	±0.02258
PVALUE		0.000**	0.000**	0.000**	0.000**
5000	*MEAN*	0.6267	0.715	0.8267	0.9067
	S.D	±0.02160	±0.02739	±0.02944	±0.02160
25000	*MEAN*	0.745	0.8467	0.955	1.0617
	S.D	±0.01378	±0.02422	±0.02588	±0.02483
PVALUE		0.000**	0.000**	0.000**	0.000**
5000	*MEAN*	0.6267	0.715	0.8267	0.9067
	S.D	±0.02160	±0.02739	±0.02944	±0.02160
30000	*MEAN*	0.7733	0.885	0.9933	1.1033
	S.D	±0.01211	±0.01871	±0.02733	±0.02338
PVALUE		0.000**	0.000**	0.000**	0.000**

*** - DENOTES SIGNIFICANCE AT 5% CONFIDENCE LEVEL**

**** - DENOTES SIGNIFICANCE AT 1% CONFIDENCE LEVEL**